URBAN WATER MANAGEMENT IN KINGSTON, NY:
PLACING GREEN INFRASTRUCTURE IN TEMPORAL & SPATIAL CONTEXT

A Thesis

Presented to the Faculty of the Graduate School

of Cornell University

In Partial Fulfillment of the Requirements for the Degree of

Master of Science

by

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December 2018

ABSTRACT

Although urban runoff is a known cause of impairment for waterbodies, questions remain about the effectiveness of best management practices like green infrastructure. In this thesis, I examine water management in Kingston, NY at several temporal and spatial scales. The study focused on green infrastructure practices installed in two municipal parking lots in Kingston, NY, within the Tannery Brook watershed. The research included a quantitative assessment of water level in green infrastructure practices every minute, a qualitative assessment of design and adaptive management in the overall parking lot site over several seasons, and a review of the history of the Tannery Brook watershed over 350 years.

Water level was measured with pressure transducer sensors in 10 green infrastructure practices (2 rain gardens, 3 bioretention areas, and 5 dry wells) for 28 storms between May and November, 2017. Maximum water depth and time to drain were calculated; these parameters were selected because of their importance to practice design and runoff reduction. All 10 green infrastructure practices included in the study infiltrated runoff very rapidly. However, design and maintenance decisions may compromise their performance over time.

Frequent visual observations provide context for water level data, along with important lessons learned for future installations. Particular issues observed in Kingston’s Uptown municipal parking lots included vehicular and pedestrian transportation flow, sediment and leaf litter that could clog practices, decreasing vegetation due to mowing, and erosion within the practices. These problems could be mitigated with improved design or adaptive management to improve maintenance over time.

The Tannery Brook has provided numerous ecosystem services to Kingston over its long history, supporting economic development in different ways. The Tannery Brook provided power to grind grain at Kingston's first mill, water for various industries (including three tanneries), and waste removal as Kingston constructed sanitary and storm water infrastructure. Portions of the Tannery Brook were eventually buried to reduce flooding. Although the Tannery Brook has largely been fragmented and forgotten, it has not been forgotten by everyone, as it continues to cause damage through infrastructure failure and localized flooding. As Kingston works to adapt to climate change, conserve natural resources, and improve sustainability, it would be worthwhile to reassess how urban streams like the Tannery Brook could support the city's values today.

The arts provide an opportunity to reimagine the form and function an urban stream could take. Two installations, one in a more traditional gallery setting and one participatory site-specific installation, provided space for Kingston residents and stakeholders to discuss what the Tannery Brook meant to them, and what it could be like in the future. Given the rapid infiltration of the green infrastructure practices within the municipal parking lots, additional green infrastructure practices constructed in the neighborhood could help reduce flooding and improve water quality. An innovative, watershed-based approach to water infrastructure could contribute to an improved urban stream system in the future.

BIOGRAPHICAL SKETCH

Emily Vail is a graduate student at Cornell University in the field of Natural Resources. She holds a Bachelor of Arts with Departmental Honors in Environmental Studies from Vassar College, and studied water quality in green infrastructure practices for her undergraduate thesis. Since 2010, Emily has worked at the NYS Department of Environmental Conservation's Hudson River Estuary Program, in collaboration with the NYS Water Resources Institute at Cornell University. She supports community-based watershed groups, municipalities, and other partners as they work to improve water quality in the Hudson Valley. Emily also organizes Uptown Swing Kingston, a monthly night of hot jazz, dance, and swing, and directs the Uptown Lowdown vintage jazz dance troupe.

ACKNOWLEDGMENTS

This multidisciplinary research has benefitted from advice, experience, information, and support from a wide range of places. I am so grateful to all of the people who have helped inform and shape this work! Thank you to:

- My committee, Todd Walter and Brian Davis;
- The New York State Department of Environmental Conservation's Hudson River Estuary Program, especially Fran Dunwell, Scott Cuppett, and Beth Roessler;
- The New York State Water Resources Institute at Cornell University;
- All of the students in the Soil & Water Lab for advice and support;
- Maureen Brull from Cornell University's Benefits Services for answering my numerous questions about the Employee Degree Program;
- Erika Mudrak from Cornell University's Statistical Consulting Unit for advice on the quantitative portion of the research;
- Jasmin Chen, for creating beautiful interpretive maps of the Tannery Brook's history and assisting with curating the Fragmented & Forgotten exhibit;
- The City of Kingston, especially Mayor Steve Noble, Ralph Swenson and Alan Adin (Engineering Department), Julie Noble (Department of Parks and Recreation), Joseph Chenier and Eddie Boyle (Department of Public Works), and Addie Farr (Art & Cultural Affairs);
- Ulster County, especially Amanda LaValle (Department of the Environment);
- Local history experts in Kingston, especially Friends of Historic Kingston and Senate House State Historic Site;

- Watershed colleagues Katherine Meierdiercks and Michael Finewood for advice on the green infrastructure and Tannery Brook history chapters, respectively;
- RUPCO, the Lace Mill, Felix Olivieri, Judith Zelda Miller, and Rubi Rose for assistance organizing, promoting, and documenting the Fragmented & Forgotten exhibit;
- O+ Festival, Buddy Valentine, and all of the volunteers for assisting with the Tracing the Tannery Brook installation;
- Timely Signs and Main Printing for printed materials at both exhibits;
- Kristopher Konyak for graphic design and visual editing; and
- Everyone who has provided support along the way.

Funding support for this work comes from the New York State Water Resources Institute at Cornell University and the NYS Department of Environmental Conservation Hudson River Estuary Program, with support from the NYS Environmental Protection Fund.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Stormwater impacts to urban streams are well documented (Walsh et al. 2005a, National Research Council 2009). Conventional stormwater systems have not solved urban water problems, but instead have traded off localized urban flooding for water quality issues and hydro-modification (Green Nylan & Kiparsky 2015). Not only do existing stormwater systems exacerbate the impacts of impervious surfaces on waterbodies, but they have also captured base flow and re-engineered urban stream networks. In many cities, first order streams were replaced by storm sewers, inextricably linking natural resources with engineered infrastructure (Kaushal & Belt 2012). As Jarden et al. (2016) noted, "…headwater streams are being replaced by headwater streets." Urban infrastructure directly influences urban waterways, and we need to consider this relationship to understand and improve urban streams.

Hydrology can be understood at a time scales ranging from minutes to centuries. Kaushal & Belt (2012) recommended "the urban watershed continuum" as a conceptual framework, and encouraged urban watershed managers and scientists to consider the evolution of urban streams fluxes of materials and energy across both spatial (meters to kilometers) and temporal (minutes to centuries) scales. We need to expand our concept of urban stream "restoration" to include land use, historical infrastructure, and other impacts.

This study integrates the assessment of urban water in Kingston, NY across a range of spatial and temporal scales. It includes monitoring individual engineered stormwater practices every minute, assessing how water level changes over the course of a storm. It examines design features and maintenance across a site at an annual scale, along with seasonal changes. It also expands outward to include the historical and watershed-wide context, covering about 350 years of change. This is a unique approach that can provide new insight to old problems. By examining these same issues over vastly different spatial and temporal scales, it can illuminate opportunities outside of traditional stormwater management studies. It places green infrastructure, as a present-day tool, within a broader, critical historical context to understand how we can move forward in a more sustainable way.

Many studies have pointed to the importance of solving urban stream problems by working within the watershed, including building small-scale, distributed stormwater practices (Walsh et al. 2005a, Walsh et al. 2005b, Vietz et al. 2016). In this way, the health of urban streams are intimately connected to land use and infrastructure within the urban watershed or sewershed. Given the hydrologic connectivity of the storm sewer system, land in the watershed may play a role in processing or transforming materials similar to riparian areas along more natural streams (Kaushal & Belt 2012). This represents an opportunity to rethink ecosystem services in urban watersheds and how practices like green infrastructure function within a broader context.

The term “green infrastructure” encompasses a variety of practices designed to manage and treat stormwater by reducing runoff through infiltration, evapotranspiration, and capture and reuse of stormwater (NYS DEC 2015). These practices generally use soils, vegetation, and engineered media to store and infiltrate runoff, rather than traditional hard (or "gray") collection and storage structures for stormwater (NYS DEC 2015). Green infrastructure can also include natural features like forests, wetlands, and floodplains, and planning for green infrastructure can be conducted at a variety of scales (NYS DEC 2015).

Green infrastructure is a unique form of water infrastructure in that it is above-ground and allows water to be visible, even temporarily as it is ponded during a storm. It allows people to engage with water infrastructure, as they are able to see and interact with these systems in a different way than traditional, underground infrastructure (Cording et al. 2017). We can use this entry point to show other, more hidden aspects of urban water infrastructure, including sewer networks and buried streams. Telling a watershed's story can help visualize these hard-to-see issues, shedding light on problems that may literally be buried underground. Making technical information accessible as stories helps engage stakeholders from more diverse backgrounds, bringing them together to talk about water resource management in urban areas in a more comprehensive way.

This multidisciplinary approach used art in particular as a storytelling device. This allowed for a two-way interaction, where technical information was shared with residents, who in turn shared information about their first-hand experiences and observations. Cities are complex and dense spaces. Many socio-economic dynamics relate directly or indirectly to water issues, along with the physical, chemical, and biological dynamics that are more typically considered. We will need to think creatively about these problems. By bringing in elements of the humanities (including history, art, and storytelling) with more traditionally technical disciplines (such as engineering, landscape architecture, environmental science, and urban design) we can foster new connections and broaden our set of strategies. Urban systems require an interdisciplinary approach, including engineering, hydrology, and socio-economics, and understanding the past can inform present-day management decisions (Kaushal & Belt 2012).

Green infrastructure is a valuable tool for reducing runoff and improving water quality. A common goal of green infrastructure is to "restore natural hydrology" or "replicate pre-development hydrology" (NYS DEC 2015). While this may be a useful concept to mitigate new stormwater impacts from greenfield or new development, the concept of "pre-development hydrology" doesn't really exist for retrofits in urbans area, where stormwater has been managed in various ways for a long time (Dufour & Piegay 2009). These are places with deep histories of water management, and even if we understood what pre-development hydrology looked like, it may not be a realistic, appropriate, or desirable goal. However, an understanding of the historical context of water flows can help us make sense of current-day issues and possible ways to resolve in a way that moves forward.

Understanding this history helps put current stormwater best management practices into context, and critique them with a historical view. We lose a sense of what urban streams could or should look like, when we are used to seeing them only in certain highly modified ways. We can learn more about how historic values have translated to the form and function of urban streams. This historic perspective can illustrate how dramatically conditions have changed, and allow us to imagine other possibilities for the future.

It will be critical to identify opportunities to make cities more sustainable, with increasing populations in urban areas, development, and climate change threats (Pickett et al. 2013). In addition to environmental improvements, social and economic sustainability are necessary components for long-term planning. While many cities have new opportunities for economic revitalization, gentrification may threaten urban equity. Kingston, NY is an excellent case study for both the challenges and opportunities in a post-industrial, Northeastern city with a long history of water management.

1.2 BARRIERS TO GREEN INFRASTRUCTURE

Although green infrastructure has become increasingly accepted as a technique to reduce runoff and improve water quality, questions remain about its effectiveness in the field (Clean Water America Alliance 2011, Vail & Meyer 2012, Driscoll et al. 2015, Green Nylen & Kiparsky 2015). There may be a disconnection between stakeholder expectations and actual performance, especially since performance is so dependent on local conditions (Driscoll et al. 2015). Quantifying runoff reduction is an important step to help communities understand how stormwater practices work and overcome barriers to more programmatic implementation (Green Nylen & Kiparsky 2015). Better predictions of performance can set up realistic expectations on green infrastructure in urban areas, and increase confidence that this investment will be worthwhile.

Specific barriers to green infrastructure at a municipal scale include concern about cost-effectiveness, lack of interdepartmental coordination, and lack of technical capacity and expertise (Driscoll et al. 2015). On the other hand, enabling factors include learning from the experiences of other communities, considering the social benefits of green infrastructure, and collaborating with diverse community groups and stakeholders (Driscoll et al. 2015).

A 2012 survey of barriers to green infrastructure in the Hudson Valley helps place these national trends within a local context. The largest cited barriers to implementing green infrastructure in Hudson Valley communities were cost, lack of knowledge, and unfamiliarity and resistance from local governments (Vail & Meyer 2012). These last two categories often overlapped, and this speaks to the importance of municipalities understanding green infrastructure technical information, along with short- and long-term costs (Vail & Meyer 2012). There was also an indication that the right information was not getting to decision-makers. Although "research hasn't proven benefits yet" was one of the lowest ranked barriers across all respondents, municipalities ranked this substantially higher than average; landscape architects, builders, and engineers ranked this higher than average (Vail & Meyer 2012). Municipalities also ranked "not enough information about costs and benefits" substantially higher than average (Vail & Meyer 2012). There is a need to target practical information to these key decision-makers to improve more mainstream adoption of green infrastructure, especially as this group was identified as a barrier by other respondents (Vail & Meyer 2012).

An improved understanding of water quality and green infrastructure has been identified as a priority for the Hudson River estuary and its watershed. The *Hudson River Estuary Action Agenda 2015-2020* is a conservation and restoration blueprint for the Hudson River estuary ecosystem. Its first long-range target for Clean Water states: "Water quality in the estuary, its tributaries, and watershed is maintained and improved to support municipal drinking water supplies, swimming and other types of water-based recreation, as well as aquatic life" (NYS DEC Hudson River Estuary Program 2015). The *Action Agenda* also includes the 2020 outcome that: "Green infrastructure is used where feasible and cost effective to achieve more pollution reduction in the estuary, and the effectiveness of green infrastructure as a tool for improving water quality is better understood" (NYS DEC Hudson River Estuary Program 2015). This research seeks to meet these local needs to support water quality improvements in the Hudson River estuary and its watershed.

The City of Kingston, NY is located on the Hudson River in the mid-Hudson Valley, and this case study offers an opportunity to understand the effectiveness of green infrastructure practices to reduce runoff in the field. Green infrastructure's role in detaining and infiltrating stormwater runoff is fundamental to its water quality benefits and associated processes. Stormwater quantity also has implications for localized and riverine flooding, managing extreme storms, reducing combined sewer overflows, and improving stream ecology or geomorphology that may be harmed by flashy runoff patterns. As a resilience tool, an improved understanding of green infrastructure can help communities adapt to climate change impacts, including more extreme weather.

This research assesses the effectiveness of green infrastructure and local conditions in the field to better understand how these practices can be used to improve clean water in communities throughout the Hudson River estuary watershed. This project provides a detailed case study to share lessons learned on performance, design, and maintenance to overcome the barriers identified by local stakeholders. The history of the Tannery Brook in Kingston is also an excellent case study for understanding water management decisions over time, and this information can be extrapolated to rivers and streams in other cities.

One of the primary goals of this applied research was to share technical information in accessible forms. Given the practical application of this work for environmental managers, English units (inches, feet, miles, etc.) are used throughout, rather than the International System of Units (cm, meters, kilometers, etc.).

1.3 STUDY SITE BACKGROUND

The City of Kingston is located on the Hudson River between the Rondout Creek and the Lower Esopus Creek in Ulster County, New York. As of July 2017, Kingston's population was estimated to be 23,169 people (United States Census Bureau 2017). Average annual precipitation is between 45 and 50 inches per year (Northeast Regional Climate Center 2018).

In 2007, the New York State Department of Environmental Conservation (NYS DEC) listed the lower segment of the Lower Esopus Creek (from the confluence with the Tannery Brook in Kingston to its mouth in Saugerties) as having "Minor Impacts" in the NYS DEC's Priority Waterbodies List (NYS DEC 2007). This segment is Class B, with an identified "best use" of swimming or other contact recreation; however, public bathing, aquatic life, and recreation were all considered stressed (NYS DEC 2007). Urban/storm runoff was documented as a known source of pollution, particularly for phosphorus (NYS DEC 2007).

In 2012, the United States Environmental Protection Agency (US EPA) appended this segment ("Esopus Creek, Lower, Main Stem"), along with the upstream segment ("Esopus Creek, Middle, Main Stem"), to the Section 303(d) List of impaired waterbodies. The specific cause/pollutant was turbidity, and suspected source was stream erosion (NYS DEC 2016).

The City of Kingston applied to Round 11 of the NYS DEC's Water Quality Improvement Program grants in 2013 to improve stormwater management in municipal parking lots within the Esopus Creek's watershed. The "Kingston Uptown Parking Area Green Infrastructure Project" was submitted as a nonagricultural nonpoint source abatement and control project, with a primary goal of reducing sediment loading into the Lower Esopus Creek (City of Kingston 2013). Other anticipated benefits of the green infrastructure project included reducing heat island impacts of the blacktop, aesthetics benefits, shading, traffic calming, and improving the continued redevelopment of Uptown Kingston (City of Kingston 2013).

The grant application identified the affected waterbody as "Lower Esopus Creek, Middle and Minor Tribs" (Water Index Number H-171, Priority Waterbodies List segment number 1307-0003, City of Kingston 2013). This segment extends from the Ashokan Reservoir to the confluence of the Tannery Brook at Kingston, and is Class B and B(T). In addition to the impacts documented in the Priority Waterbodies

List and Section 303(d) List, the City of Kingston noted that turbidity, algal blooms, and invasive vegetation in this segment of the Lower Esopus Creek impacted stream health and made public contact unpleasant (City of Kingston 2013).

NYS DEC awarded the Water Quality Improvement Program grant in 2013, and the City of Kingston contracted with engineering firm Barton & Loguidice, D.P.C. to design and manage the project. Barton & Loguidice subcontracted for general construction, including removing existing pavement and stormwater structures and installing new pavement, striping, green infrastructure, and landscaping.

The grant application included several green infrastructure stormwater retrofits in the two municipal parking lots on North Front Street (Kingston Uptown Parking Lots). Total cost of the project was $488,207.91, with $365,831.00 requested for the grant and $122,376.91 as match (25.07%, City of Kingston 2013). For more detail on the project’s budget, see Appendix A.

Study Location

This study focused on the two Kingston Uptown municipal parking lots on North Front Street in the Uptown neighborhood (also called the Stockade District), within the Tannery Brook watershed. Together, the two parking lots were approximately 1.5 acres, and provided parking both for commercial and residential purposes (City of Kingston 2013). They were located directly across the street from each other, near the intersection of North Front Street with Crown Street (65 North Front Street, Kingston, NY, 12401). The parking lots were originally constructed in

1965 to provide parking for the business district, and remained an important asset in a dense commercial area.

Kingston is considered an urbanized area with a Municipal Separate Storm Sewer System (MS4) program, as required by EPA's Phase II Stormwater Rule. Although these parking lots were part of the separate storm sewer system, much of the City of Kingston is served by a combined sewer system that discharges into the Rondout Creek. While parts of Kingston are considered Potential Environmental Justice Areas by the NYS DEC, this project was not located in an identified Environmental Justice area (NYS DEC Office of Environmental Justice 2000).

The primary soil type at this site is RvA Riverhead fine sandy loam, Hydrologic Soil Group B, and is considered well-drained (City of Kingston 2013). Depth to water table is 30 feet (City of Kingston 2013). Bedrock geology is predominantly limestone, with materials of the Onondaga Limestone and Ulster Group (Mickelson 2018).

The Uptown Kingston municipal parking lots are approximately 1,000 feet south of the Lower Esopus Creek, and within the watershed of the Tannery Brook (City of Kingston 2013, Figure 1.1). The Tannery Brook is a small, highly-modified stream that runs approximately 2 miles through Uptown Kingston (Heady 2014). It drains approximately 1.4 square miles of urban and suburban development (U.S. Geological Survey 2018). The Tannery Brook and its watershed have been greatly impacted by stormwater and wastewater infrastructure, along with in-channel modifications. (For more information on the Tannery Brook and its historical context, see Chapter 4: Tracing the Tannery Brook.)

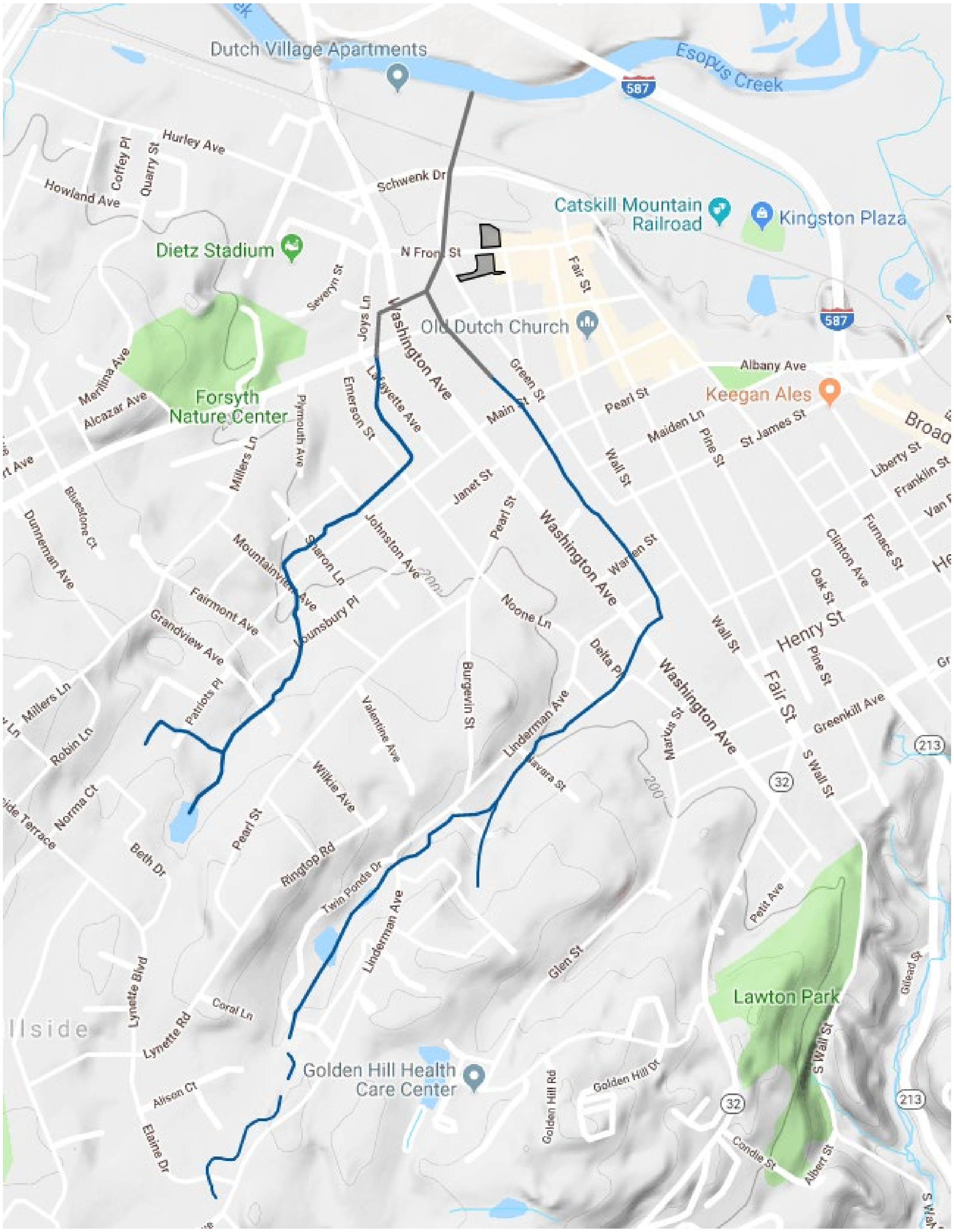

Figure 1.1: Map of Uptown Kingston, including the Uptown municipal parking lots (gray polygon). The Tannery Brook and Main Street Brook (blue lines) both flow north to the Lower Esopus Creek. The gray lines indicate the approximate location of where the Tannery Brook is piped and buried. (Base map from Google maps, Tannery Brook and Main Street Brook delineations from Mickelson 2018.)

Pre-Construction Conditions

Prior to construction, both the South and North parking lots were in need of repair. They had substantially cracked asphalt that had been repaired in small pieces, creating a very uneven surface. The parking lots were also poorly lit, and parking stripes had faded.

The South parking lot had three stormwater catch basins connected to the storm sewer line on North Front Street, which discharged into a portion of the Tannery Brook that was piped and buried (Figure 1.2). This parking lot also had three large trees, which were removed during construction. The roots of these trees had buckled the asphalt considerably.

The North parking lot did not have catch basins. Runoff would form large puddles or sheetflow to the north of the parking lot and down a steep vegetated slope (Figure 1.3). Downslope are parking lots owned by Romeo KIA of Kington and another, adjacent to Stockade Drive. The North parking lot also had two large vegetated planter boxes; these planters were located throughout the Uptown neighborhood (Figure 1.4).

Both parking lots received runoff from downspouts of adjacent properties, although these were not accounted for in the green infrastructure modeling calculations. These included the Kingston City School District building, a pharmacy, and an optometrist building for the South lot, and a restaurant for the North lot.

Despite the poor drainage, particularly in the North parking lot, the cracks in the asphalt of both parking lots also could have allowed for substantial infiltration through the paved surface.

Figure 1.2: Pre-construction conditions in the South parking lot, including existing catch basins, trees, and guardrail (July 18, 2016).

Figure 1.3: Pre-construction drainage in the North lot. As there were no storm drains or connections to the storm sewer system, runoff would flow to the north edge and run down the steep slope (top, from July 18, 2016). A storm drain in the parking lot below the slope (bottom, from August 8, 2016) likely collected runoff from the North lot.

Figure 1.4: Pre-construction conditions in the North parking lot, including planter boxes with vegetation (July 18, 2016).

Post-Construction Conditions

Barton & Loguidice completed engineering designs for the parking lots and green infrastructure in August 2015. Since the project was considered a retrofit, practices were not required to meet the standards in the NYS Stormwater Management Design Manual. However, the designed practices were representative of good design practice (Waldron, personal communication, September 2, 2016). This project required a Stormwater Pollution Prevention Plan (SWPPP) as part of the construction permit, which was approved by NYS DEC Region 3 staff in March 2016 (NYS DEC 2016).

Before construction, consultants conducted infiltration tests on three test pits, including two in the North lot and one in the South. Stabilized infiltration rates were calculated at two of the three pits. Although the parking lots had a variety of materials (including fill, stone, and crushed shale) base soils were coarse sand (Barton & Loguidice 2015a). For more information on the test pit results, see Appendix B. An old building foundation was found in Test Pit 1, and according to the construction team, they also found an old cistern that had previously been filled in.

This project planned to replace more than 7,500 square feet of asphalt with green space (City of Kingston 2013). Although the grant originally called for tree pits, bioretention areas, and vegetative buffers, the final plans included dry wells, bioretention areas, and pervious pavers (City of Kingston 2013, Barton & Loguidice 2015a).

Construction on the South lot began on August 1, 2016, and was completed by September 12, 2016. Construction on the North lot began on September 12, 2016, and completed by October 17, 2016. Bioretention areas in both lots were planted on October 13, 2016.

In the South lot, two bioretention areas (with underdrains), one rain garden (without an underdrain), three dry wells, and one section of pervious pavers were installed. In the North lot, one bioretention areas, one rain garden, two dry wells, and two sections of pervious pavers were installed. See Figure 1.5 for engineering plans and green infrastructure locations for both parking lots, and see Figure 1.6 for designed drainage areas. For general specifications about the practice types, see Appendix D. For detailed specifications of the individual green infrastructure practices, see Appendix E.

As part of the design, Barton & Loguidice used HydroCAD to calculate runoff reduction for each practice for 2-, 10-, and 100-year storms (Barton & Loguidice 2015b). Across both parking lots, the runoff area was 32 ft^2 smaller after construction, and modeling indicated that runoff volume and peak flow runoff were reduced (Table 1.1, Barton & Loguidice 2015b). All of the impervious area of the parking lots was treated by green infrastructure stormwater practices, with the exception of one small section (5,590 ft^2) of the South parking lot that continued to have runoff directed into Green Street (Barton & Loguidice 2015b).

Table 1.1: Modelled change in runoff values from pre-construction to post-construction, totaled across both parking lots. (Barton & Loguidice 2015b) For a more detailed summary of pre- and post-construction runoff, see Appendix C.

Recurrence Interval	**Storm Size (in)**	**Runoff Area (ft^2)**	**Runoff Volume (af)**	**Peak Flow Runoff (cfs)**
Water Quality Volume	2.0	-32	-0.154	-0.59
10 year	4.69	-32	-0.386	-0.50
100 year	8.31	-32	0.020	-0.21

The City of Kingston also calculated pollutant load reductions using EPA Region 5 Model (STEPL, or the Spreadsheet Tool for Estimating Pollutant Load). This model estimated that bioretention/infiltration practices at the two parking lots would reduce 0.8 tons/year of sediment, 3.4 pounds/year of phosphorus, and 17.4 pounds/year of nitrogen to the Esopus Creek (City of Kingston 2013).

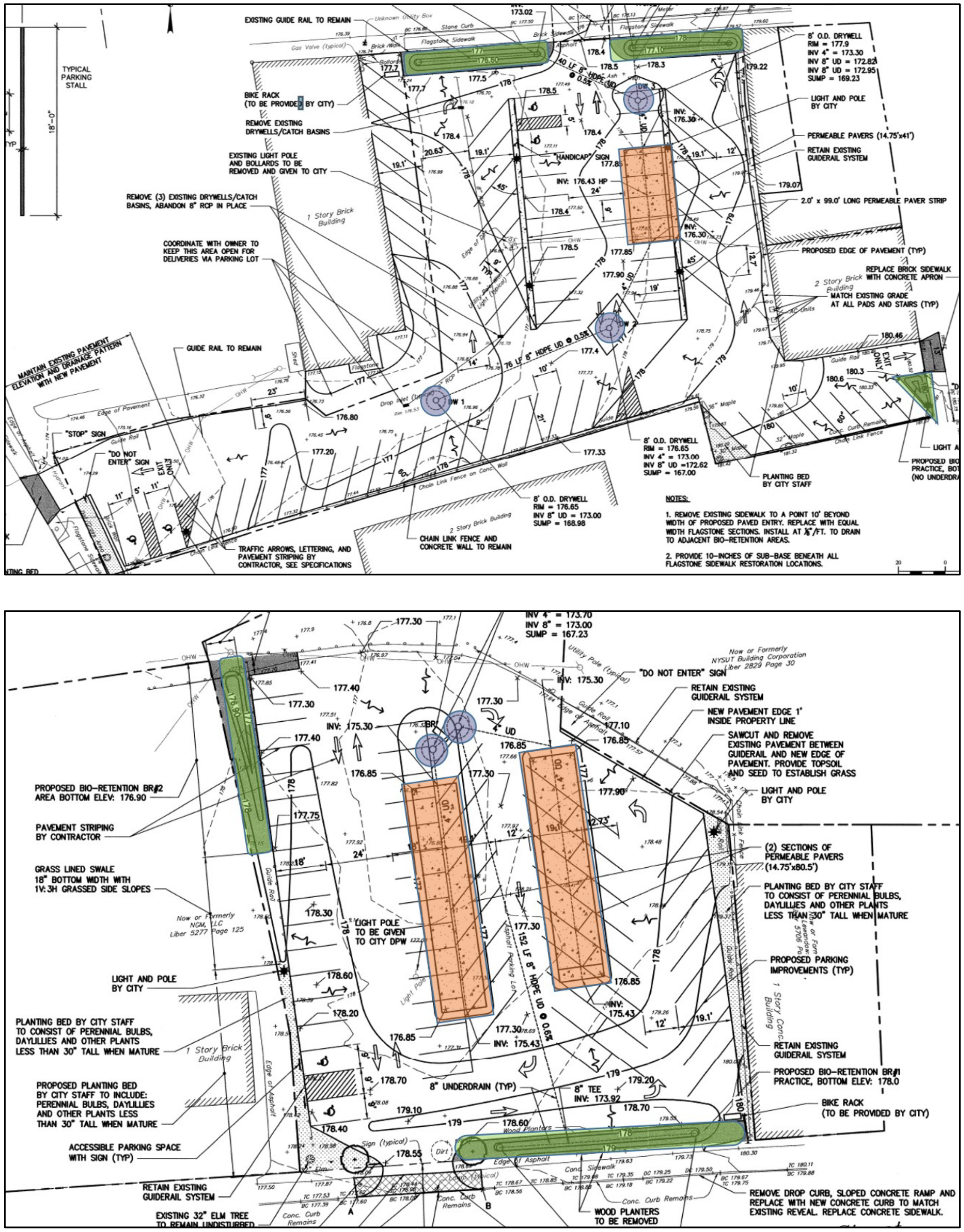

Figure 1.5: Engineering plans for the South lot (top) and North lot (bottom), showing bioretention areas and rain gardens in green, pervious pavers in orange, and dry wells in purple (from Barton & Loguidice 2015a, colors added).

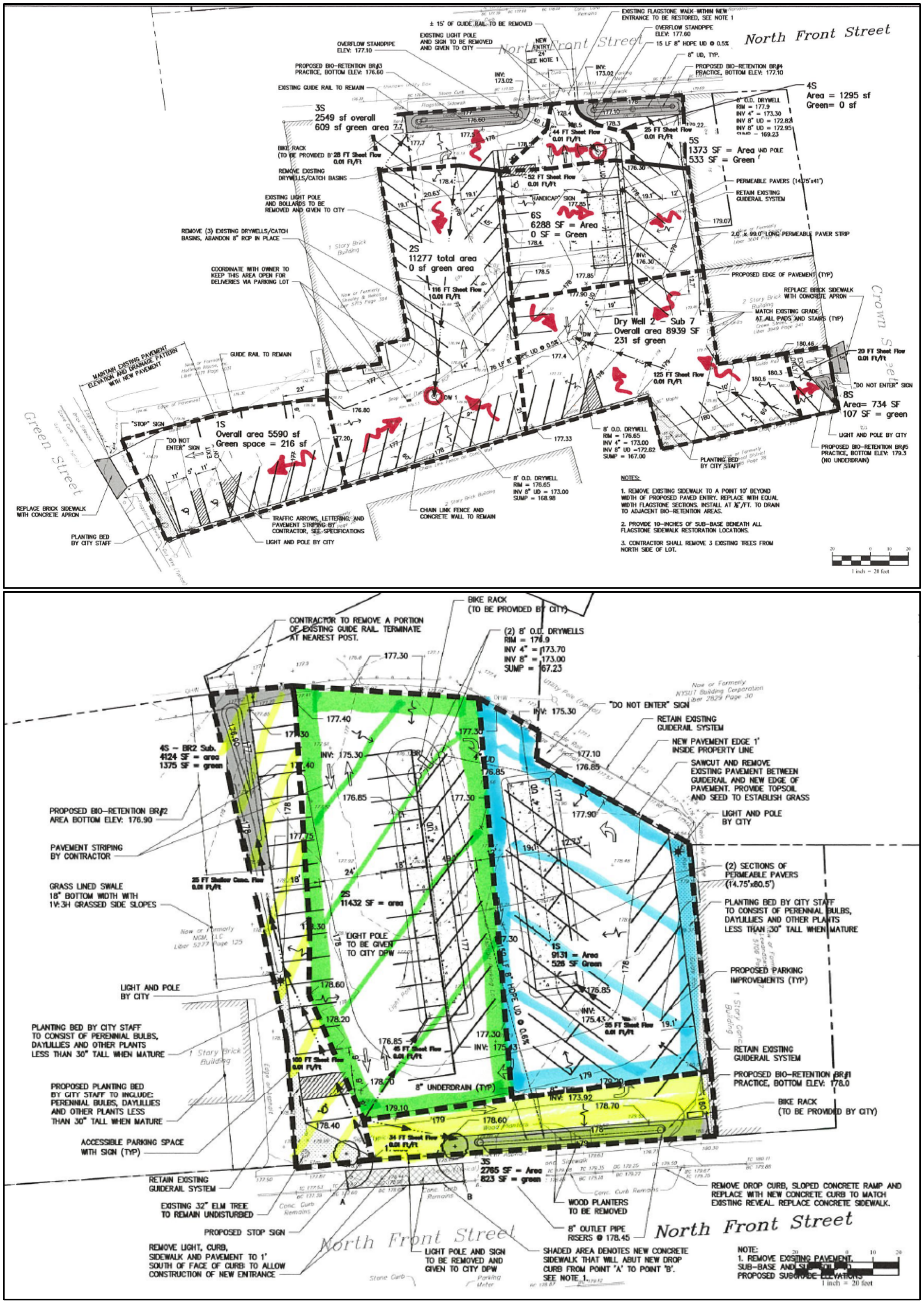

Figure 1.6: Post-development drainage map of the South lot (top, Barton & Loguidice 2015d) and North lot (bottom, Barton & Loguidice 2015c).

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CHAPTER 2

QUANTITATIVE ASSESSMENT OF GREEN INFRATRUCTURE

2.1 INTRODUCTION

Green infrastructure's ability to manage stormwater quantity has implications for localized and riverine flooding, managing extreme storms, reducing combined sewer overflows, and improving ecology and geomorphology in urban streams that may be harmed by flashy runoff patterns. How water moves through a green infrastructure practice is the foundation for its overall function and performance, and water quantity performance also impacts the potential water quality benefits (Driscoll et al. 2015, NYS DEC 2015). These quantity-quality dynamics extend past the individual practice scale to the broader urban watershed scale. Water quantity changes in base flow and stormwater flows in urban streams have impacted their biogeochemical cycles and the processing of nutrients and other materials (Kaushal & Belt 2012).

Local site conditions significantly impact hydrologic performance of green infrastructure practices, especially for retrofits in urban areas (Hopton et al. 2015). In one review, average water retention performance of green infrastructure was shown to vary more between sites than between types of practices (Driscoll et al. 2015). Average percent runoff reduction was 68.4% for bioretention areas and 72.0% for porous pavements when individual sites were compared; however, for all storm events across all sites, average runoff reduction was 90.3% for bioretention areas and 57.5% for porous pavement (Driscoll et al. 2015). Practitioners and managers need more detailed information on what drives this variability, and what mechanisms can improve performance (Green Nylan & Kiparsky 2015). This can inform design of green infrastructure, along with informing local expectations for these practices in the field.

Monitoring studies of green infrastructure performance, either quality or quantity, can be very expensive. Although municipalities play a large role in green infrastructure implementation, particularly retrofits, there is limited funding available for them to conduct post-construction analyses to ensure that the practices are actually functioning as intended (Liu et al. 2014). Green infrastructure may be required by permits, or be used to meet water quantity or quality goals, and certain types of monitoring may be cost-prohibitive for municipalities, government agencies, or other managers. It is useful to understand the kinds of data that lower-cost options can provide, particularly for municipalities that are required to reach certain volumetric or pollutant loading targets (Welker et al. 2013, Toran 2016).

This field study of green infrastructure practice performance assesses runoff reduction in two Uptown municipal parking lots in Kingston, NY. These two lots included 2 rain gardens, 3 bioretention areas, 5 dry wells, and 3 sections of pervious pavement.

2.2 METHODS

Construction of the Uptown municipal parking lots and green infrastructure practices was completed in October 2016. Onset HOBO pressure transducers (U20 Water Level Logger U20-001-0x-Ti) were installed in the 5 dry wells on November

22, 2016 and in the 3 bioretention areas and 2 rain gardens on November 23, 2016. The 3 sections of pervious pavers were not included in the quantitative portion of this study.

None of the practices were designed with inlets or forebays, and runoff was designed to enter as sheetflow from all sides. They were also designed without a specific outlet for maximum infiltration. The bioretention areas and dry wells were designed with overflow pipes for extreme weather, and these were connected to the other dry wells within the site. The pervious pavers also had underdrains that connected to dry wells. After construction, the parking lots were disconnected from the existing municipal storm sewer system, as all of the stormwater was designed to infiltrate on-site.

Water level was measured at the deepest point within the rain gardens and dry wells, and within the underdrain pipes for the bioretention areas. In each of the 2 rain gardens (without underdrains), a 1" perforated PVC pipe was installed and buried 3 feet under the soil surface to house the HOBO, at the deepest part of the practice. The HOBOs were hung from the top of the PVC pipes and rested at the bottom. In each of the 5 dry wells, a 1" perforated PVC pipe was installed and buried 1 foot in the gravel to house the HOBO. In each of the 3 bioretention areas (with underdrains), the HOBOs were hung from the overflow riser and rested in the underdrain. An extra transducer to measure barometric pressure was hung, suspended, within the overflow riser in Bioretention Area North.

The HOBOs logged pressure and temperature every minute, and data from the sensors were downloaded every 2 weeks with a HOBO Waterproof Shuttle (U-DTW-

1). Pressure measurements were converted to water level depth in each of the green infrastructure practices using Onset HOBOware Pro software.

This study design is similar to other studies of urban green infrastructure that use pressure transducers or water level loggers to monitor performance (Toran 2016; Winston et al. 2016).

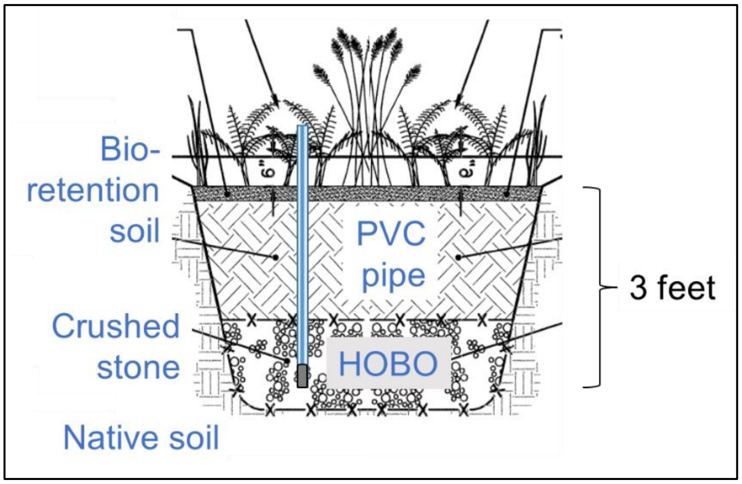

Figure 2.1: Diagram of HOBO placement in the 2 rain gardens (without underdrain) (image adapted from Barton & Loguidice 2015a).

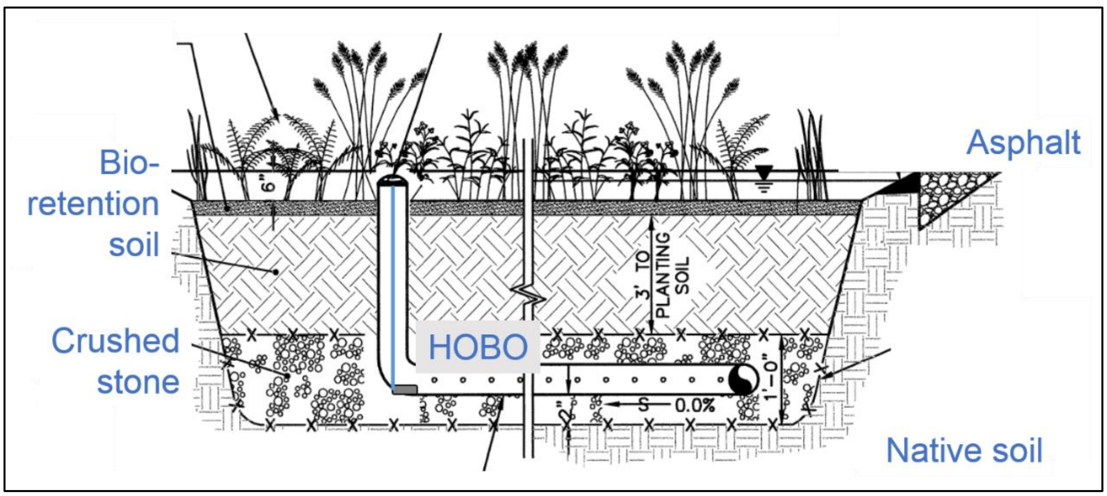

Figure 2.2: Diagram of HOBO placement in the 3 bioretention areas (with underdrains, image adapted from Barton & Loguidice 2015a).

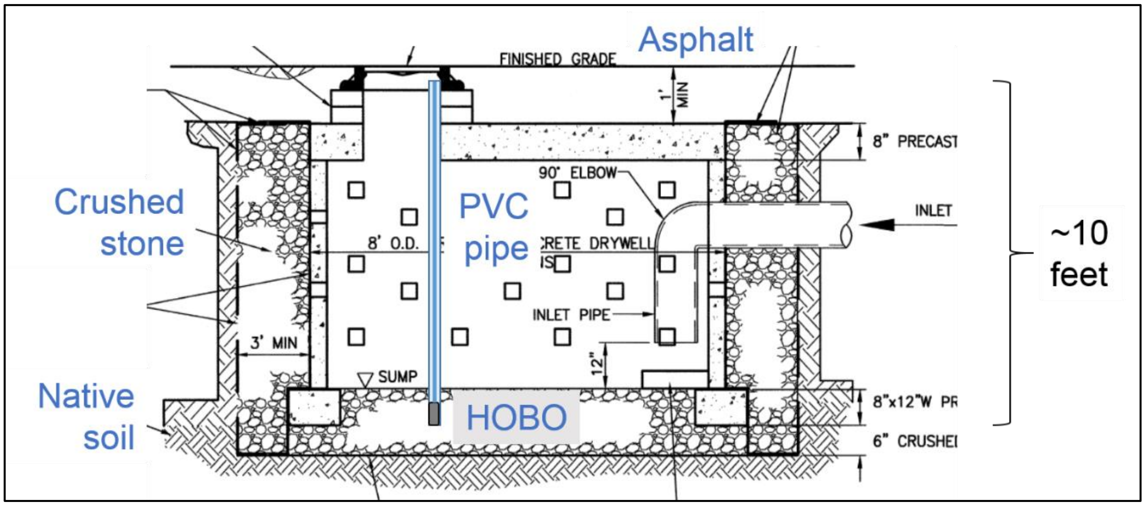

Figure 2.3: Diagram of HOBO placement in the 5 dry wells (image adapted from Barton & Loguidice 2015a).

An Onset HOBO Data Logging Rain Gauge (RG3) was installed at the site on May 5, 2017. This tipping-bucket rain gauge recorded rainfall at 0.01” intervals, along with temperature. Rain depth per minute was calculated for each storm, and these data were paired with water level depth per minute in each practice.

Between May and November 2017, 28 storms were measured, along with water level in each of the 10 green infrastructure practices. A storm was defined as a rain event with more than 0.05 inches of precipitation, after an antecedent dry period of more than 6 hours. Depth, duration, average intensity, and peak 5-minute intensity were calculated for each storm.

Water depth was measured from the location of the HOBO; this was 3 feet below the soil for rain gardens, 1 foot below the gravel for dry wells, and within the underdrain for bioretention areas. Various runoff characteristics were calculated based on rainfall and water depth measurements in each practice. These included time and depth of first peak, time and depth of maximum peak, time and depth of last peak, and time where water level was zero. To examine the time for practices to infiltrate or drain, time from last peak to zero, time from maximum peak to zero, time from last peak to zero, and time from storm end to zero were also calculated.

For this study, green infrastructure performance was based on the change in water depth in each practice over time. A “response” was defined as a clear rise, peak, and fall in water depth during or after a storm in the various practices. For some of the practices, particularly the dry wells, this peak was as short as 2 minutes.

The analysis focused on maximum water depth and time from the maximum peak to drain for each green infrastructure practice in each storm. These parameters have implications for the design and overall functioning of the green infrastructure practices. Recommendations exist for these parameters, which allows the practices to be compared against a baseline. The NYS DEC’s *Stormwater Management Design Manual*, a technical guidance document for designing green infrastructure and other stormwater practices, recommends a maximum ponding depth of 6 inches and a maximum drain time of 48 hours for the practice types that were included in this study (NYS DEC 2015).

Maximum water depth was calculated for each storm and each practice by identifying the highest water level over the duration of each storm. Many practices saw multiple peaks in water level over the course of a given storm. Time to drain was calculated for each practice in each storm by subtracting the time of the maximum water depth from the time at which the water level returned to zero for each storm. If a maximum water depth value occurred more than once during the storm, the time of the first maximum depth was used. If a new storm began while the water level was still receding, the time at which the second storm returned to zero was used for both storms. In some storms, the maximum water depth fully infiltrated before water level rose again over the course of the rain event; however, the time from maximum peak to the time of final drain down was still used.

In some cases, there appeared to have been some drift in the HOBO measurements. In those instances, a depth of zero was estimated at the time when water depth stabilized and was no longer decreasing, using water level at the minute before the storm began and other reference values representative of that particular storm's dataset. Water level data was shifted to compensate for the drift using those values.

One of the primary goals of this applied research was to share technical information in accessible forms. Given the practical application of this work for environmental managers, English units (inches, feet, miles, etc.) are used throughout, rather than the International System of Units (cm, meters, kilometers, etc.).

2.3 RESULTS

Storm Characteristics

Of the 28 storms measured, most of the storms (86%) were less than 1 inch of rain, with an average storm of 0.5 inches. All of the storms were at or below the 1-year storm for their duration (Perica et al. 2015). The largest recorded storm was October 29-30, 2017, with 2.67 inches of rain over 23.55 hours, which was about the 24-hour, 1-year storm (Perica et al. 2015). The storm with the highest peak 5-minute intensity was on August 4, 2017, when 0.29 inches of rain fell in 5 minutes. No storms exceeded the 1-year, 5-minute rainfall intensity (4.01 inches/hour, Perica et al. 2015). Two storms were at the minimum storm depth threshold of 0.05 inches (June 24, 2017 and October 11, 2017). For a summary of storm characteristics, see Table 2.1 and Figure 2.4.

Table 2.1: Summary of storm characteristics (depth, duration, and peak 5-minute intensity).

	# of storms	Mean	Mean	Min	Max
Depth (inches)	28	0.51	0.31	0.05	2.70
Duration (hours)	28	7.17	5.00	0.25	23.55
Peak 5-Minute Intensity (inches/minute)	28	0.017	0.012	0.002	0.058

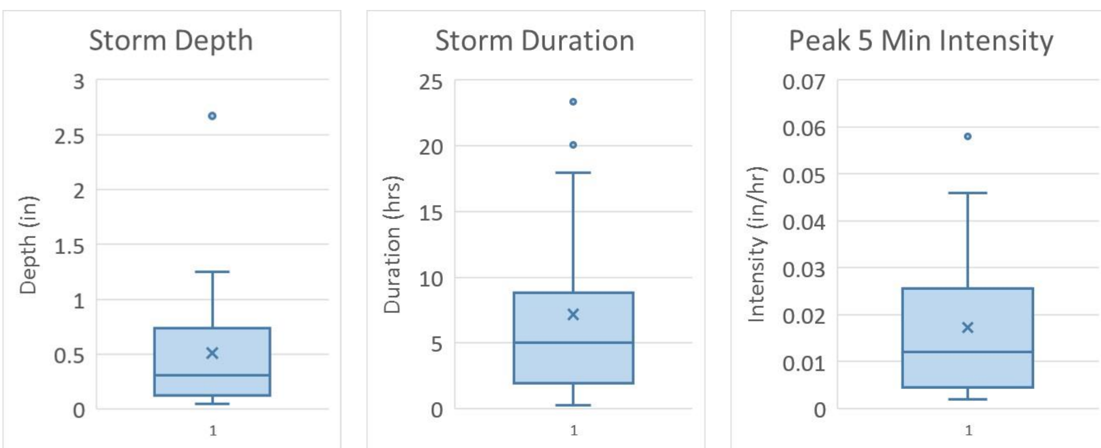

Figure 2.4: Box plots of storm characteristics (depth, duration, and peak 5-minute intensity).

Green Infrastructure Practices and Response

Table 2.2 summarizes the 13 total green infrastructure practices in the North and South parking lots. 10 of these practices (rain gardens, bioretention areas, and dry wells) were monitored. Although runoff reduction was not measured in the pervious pavers, they are included in this chart for reference on the relative size of drainage area and storage compared to the practices that were measured. For more information on individual practices, see Appendix D.

Table 2.2: Summary of green infrastructure practice designed performance and storm responses (design values from Barton & Loguidice 2015b).

Practice	**Designed storage (ft^3)**	**Designed drainage area (ft^2)**	**# of storms recorded**	**# of storms w/ response**	**Max water depth (ft)**
Rain Garden North	253	4,124	28	20	3.53
Rain Garden South	157	734	28	22	4.17
Bioretention North	410	2,765	28	9	0.10
Bioretention South 1	194	1,373	28	0	0
Bioretention South 2	575	2,549	28	0	0
Dry Well North 1	2,116	Not calculated	28	2	0.19
Dry Well North 2	2,096	Not calculated	25	20	0.50
Dry Well South 1	1,541	11,277	28	12	2.83
Dry Well South 2	3,241	8,939	28	11	1.95
Dry Well South 3	1,263	1,295	5	3	0.08
Pervious Pavers North 1	2,951	9,131	n/a	n/a	n/a
Pervious Pavers North 2	982	11,432	n/a	n/a	n/a
Pervious Pavers South	2,436	6,288	n/a	n/a	n/a

Table 2.3 breaks down the percent of the impervious surface cover treated by each practice type over both parking lots. Most of the parking lot area was treated by 3 sections of pervious pavement (44.8%) and 5 dry wells (35.9%), with a much smaller area treated by the 3 bioretention areas (11.2%) and rain gardens (8.1%).

Table 2.3: Drainage areas for green infrastructure, by practice type (Barton & Loguidice 2015b).

Practice	**North Lot drainage (ft^2)**	**South Lot drainage (ft^2)**	**Total drainage (ft^2)**	**Percent**
Rain Gardens	4,124	734	4,858	8.1%
Bioretention Areas	2,765	3,922	6,687	11.2%
Dry Wells	n/a	21,511	21,511	35.9%
Pervious Pavement	20,563	6,288	26,851	44.8%
Total	27,452	32,455	59,907	100%

Water Level Measurements

Across all the storms, maximum water depth was highest in the 2 rain gardens, followed by the dry wells (Table 2.4).

Table 2.4: Summary of maximum water depth in each practice type. These values include storms with no response, where a value of 0 was used.

Practice	**# of practices**	**Total # of storms**	**Total # responses**	**Mean (ft)**	**Median (ft)**	**Min (ft)**	**Max (ft)**
Rain Garden	2	56	42	1.80	2.31	0	4.17
Bioretention Area	3	84	9	0.01	0	0	0.10
Dry Well	5	114	49	0.17	0	0	2.83

The 2 rain gardens together responded to 42 (75%) of the measured storms (Table 2.4). 32 storms had ponding over 6 inches deep (57%), with the highest recorded depth indicating 1.17 feet of ponding in Rain Garden South (Figure 2.5). Of the storms with above-ground ponding, 10 had ponding less than 6 inches (18%), and 4 hand ponding greater than 6 inches (7%). In the rain gardens, 42 out of the 56 storms (75%) produced less than 3 feet of water depth. Since the HOBOs were buried 3 feet under the soil surface, this water would all be stored in the soil and would not result in above-ground ponding. 14 of those storms had no response in the rain gardens.

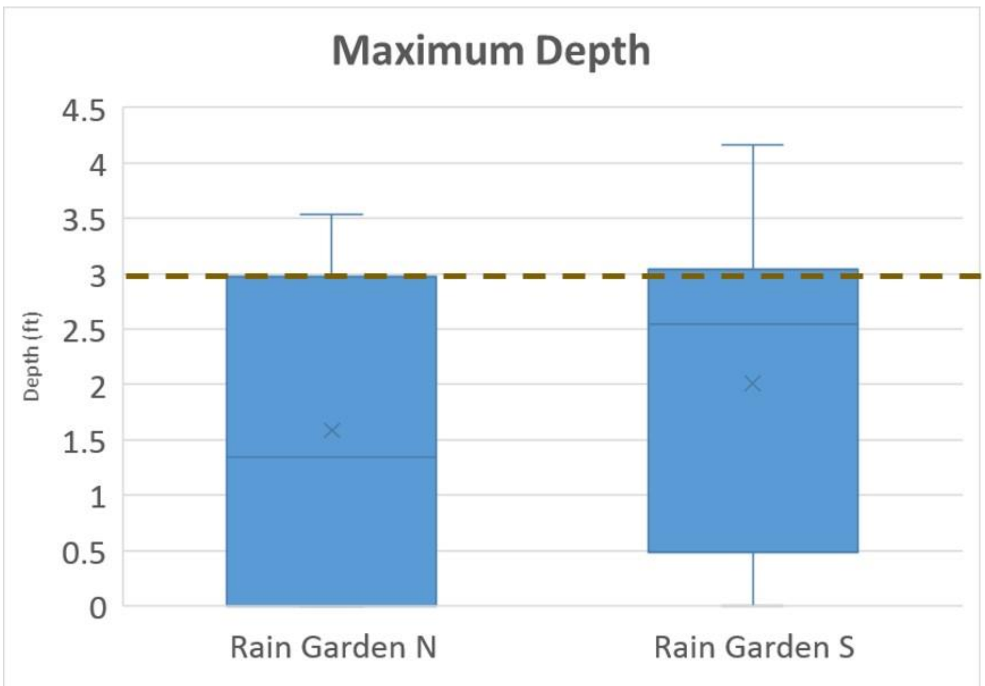

Figure 2.5: Box plot of maximum water depth per storm in rain gardens, across 28 storms. The dashed line represents the soil surface (HOBOs were buried 3 feet into the soil), and points above the line indicate ponding.

The bioretention areas did not show water level increases in the same way as the rain gardens. Because of the HOBO's placement within the underdrain, rather than in the practice's soil column, water level changes indicate water level within the underdrain specifically. Bioretention Areas South 1 and South 2 did not respond to any storms, indicating that no measurable amount of water was within the underdrain. Bioretention Area North responded to 9 of the 28 storms (Table 2.4). The maximum recorded depth within Bioretention Area North's underdrain was 0.10 feet (1.2 inches). Box plots of the bioretention areas' maximum depth were not included, due to the lack of response data from these practices.

The 5 dry wells together responded to 49 of 114 total storms (43%, Table 2.4). 65 storms produced no response in the dry wells (57%), and 40 storms had less than one foot of water level rise (35%). Only 9 storms produced above-ground ponding (8%), with a maximum depth indicating 1.83 feet of ponding (Figure 2.6).

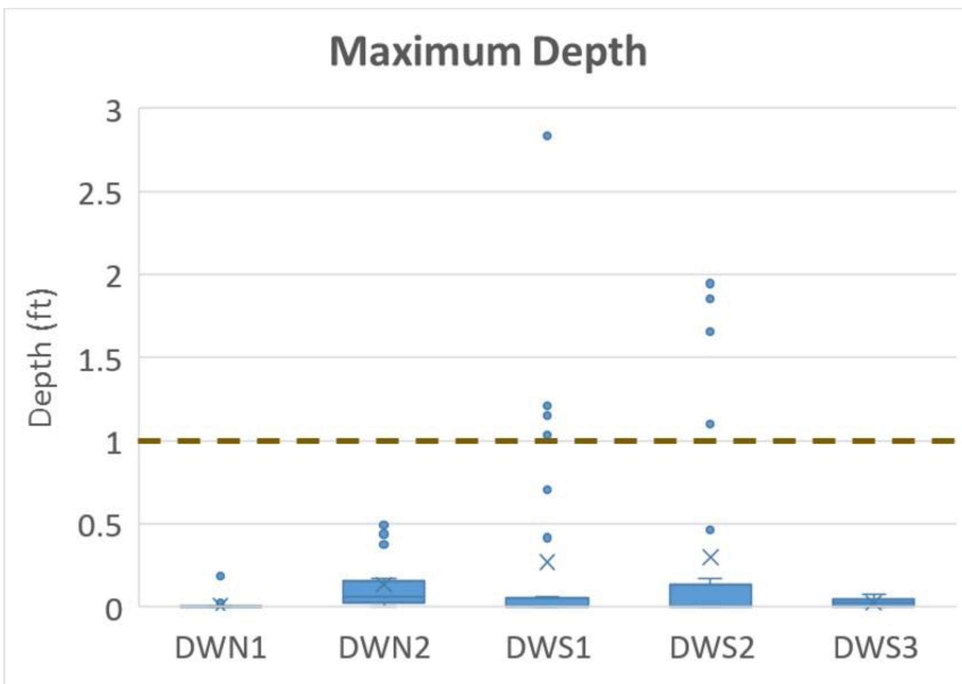

Figure 2.6: Box plot of maximum water depth per storm in dry wells, across 28 storms. The dashed line represents the gravel surface (HOBOs were buried 1 foot into the gravel), and points above the line indicate ponding.

Time to Drain Measurements

All of the practices infiltrated runoff quickly, with the majority of practices draining in under 6 hours (Table 2.5).

Table 2.5: Summary of drain down time in each practice. These values do not include the storms with no response.

Practice	**# of practices**	**Total # of storms**	**Total # of responses**	**Mean (hrs)**	**Median (hrs)**	**Min (hrs)**	**Max (hrs)**
Rain Garden	2	56	42	9.44	6.29	0.17	65.25
Bioretention Area	3	84	9	1.88	1.70	0.05	5.83
Dry Well	5	114	48	0.89	0.33	0.02	14.45

In the rain gardens, 32 out of 42 (76%) storms drained in less than 12 hours, and only one storm took longer than the recommended 48 hours to drain (Figure 2.7, NYS DEC 2015).

Bioretention North consistently drained down in less than 6 hours (9 out of 9 responses), with a maximum time of 5.83 hours. Box plots of the bioretention areas' time to drain were not included, due to the lack of response data from these practices.

In the dry wells, 40 out of 48 (83%) storms drained in less than one hour. The longest time to drain was 14.45 hours (Figure 2.8).

For more detailed information on performance in each of the green infrastructure practices, see Appendix E.

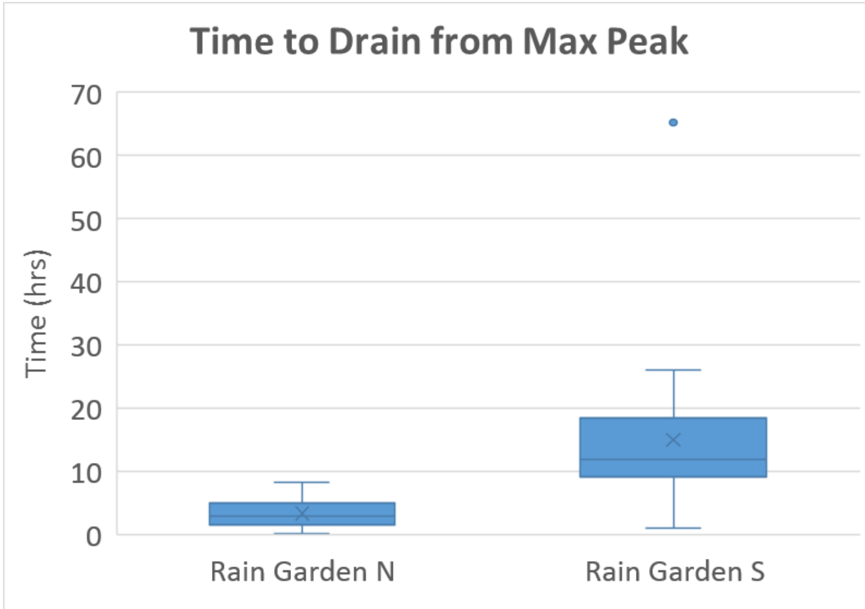

Figure 2.7: Box plot of time for rain gardens to drain, from the maximum depth to zero over the course of a storm. These values represent 20 storms for Rain Garden North and 28 storms for Rain Garden South. Note that the outlier value in Rain Garden South occurred when a new storm began before the previous storm had finished draining.

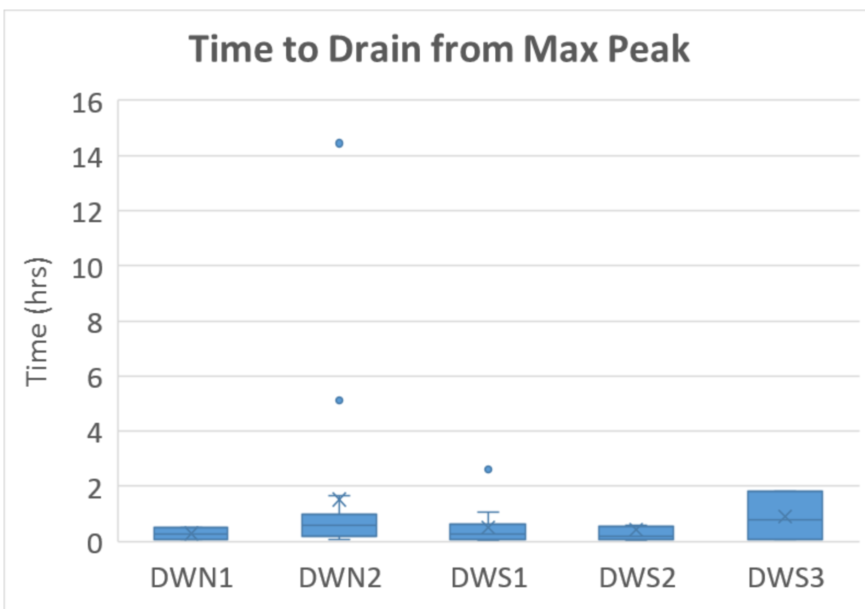

Figure 2.8: Box plot of time for dry wells to drain, from the maximum depth to zero over the course of a storm. These values represent 2 storms for Dry Well North 1, 20 storms for Dry Well North 2, 12 storms for Dry Well South 1, 11 storms for Dry Well South 2, and 3 storms for Dry Well South 3.

2.4 DISCUSSION

All of the practices monitored with HOBOs appeared to reduce runoff very quickly. Water depth measurements indicated that water was stored in the practices, particularly in the two rain gardens, but water appeared to be infiltrating very rapidly in each of the practices. Each of the green infrastructure practices responded different to storms, due to differences in design, drainage area, location on the site, and other conditions.

Each of the green infrastructure practices experienced storms with no response in water level. There were four storms (5/7/17, 10/11/17, 11/5/17, and 11/6/17) that elicited no response from any of the practices. The maximum storm depth with no response was 0.08 inches. Rain gardens had 14 storms with no response (25%), bioretention areas had 75 storms with no response (89%), and dry wells had 65 storms with no response (57%). During the storms that did not produce a response or peak in water level from rain gardens and dry wells, it can be assumed that these practices were infiltrating runoff at the same rate as the water was entering the practice. Water was observed to be draining into each of the practices, and ponding was observed in the bioretention areas, even when there was not a water level change within the underdrain.

Water ponding was deepest in the rain gardens, but runoff still infiltrated relatively quickly. 76% of storms infiltrated in less than 12 hours, compared to the 48 hour design standards (NYS DEC 2015). Only one storm took longer than 48 hours to drain, and that was when another storm began before the previous storm had fully drained down.

Rain Garden South was the most sensitive practice, and responded to 22 of 28 (79% of storms). This was the smallest and deepest practice. The smallest storm with a response was 0.05 inches (on 6/24/17). The deepest water level recorded in Rain Garden South was 4.2 feet after the highest-intensity rainfall (August 4, 2017), indicating a ponding depth of 1.2 feet. The longest duration storm on October 29, 2017 produced a water depth of 2.7 feet; all of that water was stored in the soil below the practice's surface.

Rain Garden North responded to fewer storms, had shallower ponding, and had faster drain times compared to Rain Garden South. This practice was larger and shallower, with more opportunities for infiltration across this area than the small and deep Rain Garden South. The highest recorded depth in Rain Garden North was 3.53 feet, which represented about 6 inches of ponded water.

The two south bioretention areas had no water measured within their underdrains during any storm. Water was only measured in Bioretention Area North after intense rains. This is likely because of water coming in through the overflow riser, rather than measuring water depth and ponding in the practice. The riser in this practice was located at the surface of the practice, rather than raised 6 inches per the original design and New York State design guidelines (Barton & Loguidice 2015a, NYS DEC 2015). Since visual observations indicated that water ponded in each of the bioretention areas, even when no water level change was recorded in the underdrains, it can be assumed that all of the water that entered these practices infiltrated directly into the soil, and did not collect in the underdrain. Although this does not provide information about the practices' infiltration, it does indicate that water was not flowing through the underdrains. The underdrains were designed to facilitate drainage, and to carry excess water to dry wells on-site as an overflow mechanism for the individual practices. As they were not utilizing the underdrains for overflow, the bioretention areas were treating all of the stormwater draining to them through direct infiltration to groundwater.

Across the site, it appeared as though each individual practice achieved 100% runoff reduction. The highest water level measured within an underdrain (Bioretention Area North) was 1.2 inches, and water level in the dry wells was not high enough to reach the overflow pipes. This essentially removed both parking lots from the effective impervious area within the Tannery Brook watershed.

Only 9 storms (8%) produced above-ground ponded water in the dry wells. These practices received a large proportion of runoff from the site, but appeared very effective. The deepest water levels for both Dry Well South 1 and Dry Well South 2 were recorded were on October 29, 2016. These were the two dry wells with the largest drainage areas, and they included trees lining the parking lots. Leaf litter was observed at the bottom of these practices, and may have slowed infiltration rates. Dry Well South 3 had much less data than the other practices, since this practice was located in a parking spot that was frequently inaccessible.

The dry wells also drained extremely quickly; 83% of storms infiltrated in less than one hour. Dry Well North 2 had the highest time to drain (14.5 hours), which was an outlier compared to the other drain down times for this practice and others. This may have been due to debris getting into the PVC pipe housing the HOBO within the practice; the HOBO was stuck within the PVC pipe twice over the duration of the study due to material getting into the pipe.

Overall, the storms within the study period were small in depth, duration, and intensity. During a few periods, there were technical problems with either the rain gage or the HOBOs, resulting in missing data on certain storms. A lack of data on larger storm limits the ability to predict how these practices might function with longer duration or higher intensity storm events. Nevertheless, given the infiltration rates and large storage capacity in the dry wells, they appear able to treat much larger storms than were measured in this study.

Peak 5-minute intensity seemed to drive the peak response from the practices. This has implications for green infrastructure design, especially with more intense rain storms predicted in the future due to climate change. Storm depth and duration were not as strong drivers, likely because of the rapid infiltration from the sandy base soils. Peak flow mitigation was best during low-intensity rainfall in other green infrastructure field studies (Winston et al. 2016). It remains to be seen how these practices will perform in higher intensity or longer duration storms.

Both parking lots relied heavily on dry wells and pervious pavement to infiltrate runoff (80.7% total). Although these are effective infiltration practices, they are still hardscape structures like traditional “gray” infrastructure. They may not provide the same level of co-benefits that vegetation-based practices might provide, such as shading for the urban heat island affect, reducing air pollution, sequestering carbon, improving habitat, processing nutrients, improving aesthetics, etc. (Center for Neighborhood Technology 2010, Driscoll et al. 2015, Fenner 2017). Although they are considered green infrastructure practices because of their infiltration, they are not as "green" as rain gardens and bioretention areas. While these practices were functioning over the course of the study, Pervious Pavement 2 in the North lot had already gotten clogged with fines, and may not work well into the future. The dry wells had slower infiltration in October, when leaves were observed within the practices. Maintenance for these practices will be important to ensure that they continue to function over time. For more information on observations and maintenance issues, see Chapter 3: Qualitative Assessment of Green Infrastructure.

The drainage areas for the bioretention areas seemed very small compared to their size, and these practices seemed over-designed, especially with the inclusion of underdrains. Overall, the site could have directed more water towards the bioretention areas, and less water to the pervious pavers or dry wells that may be more prone to clogging or be more difficult to maintain.

The physical conditions of the site, particularly the well-draining sandy soils and high depth to groundwater (30 feet), appear to contribute to the effectiveness of these green infrastructure practices for reducing runoff. Other green infrastructure practices that were installed in this area by Ulster County similarly infiltrate very quickly, based on visual observations (LaValle, personal communication, March 14, 2018). This area seems well-suited for additional green infrastructure infiltration practices.

Using pressure transducers to monitor water level in green infrastructure practices is an effective method of understanding physical performance, especially in supplementing other observations, reinforcing results of Toran (2016). This is a relatively low-cost form of monitoring that can yield high-resolution data on performance, which can be challenging to collect in systems that do not have a single inlet or outlet to measure runoff. Recordings every minute were necessary to capture the rapid water level peaks; in some of the practices, particularly the dry wells, a change in water level lasted as short as 2 minutes.

2.5 CONCLUSION

The 10 green infrastructure practices monitored in this study appeared to be performing well, based on water level depth and time to drain as key indicators. This study provided a baseline of green infrastructure performance in the first full growing season after construction, and included relatively small storms. Green infrastructure practices are dynamic, and their performance may change drastically based on changes in vegetation, drainage areas, maintenance, and other factors. Climate change may also impact the types of storms in the region, including more intense rainfall and extreme weather. It would be helpful to replicate this study in the future (in 5 to 10 years) to assess and compare how green infrastructure performance may change over a longer time-frame.

At a suburban watershed scale, green infrastructure has been shown to reduce peak discharge and total runoff volume (Jarden et al. 2016). However, results also indicate that although these practices have the potential to improve runoff conditions across the catchment, they do not always reach their full potential (Jarden et al. 2016). This speaks to the importance of improved design and maintenance of practices.

Fine resolution data (minute to minute across the first year of installation) is one helpful tool to assess green infrastructure performance. Water level sensors are a useful and relatively affordable way for municipalities and other managers to monitor green infrastructure performance if there is a need to quantify runoff reduction. Other indicators can provide information on how these practices function over a longer time-scale, and together as an overall site. Given the constraints on budgets and time for municipal staff, visual observations represent another important method to understand green infrastructure performance.

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CHAPTER 3

QUALITATIVE ASSESSMENT OF GREEN INFRASTRUCTURE

3.1 INTRODUCTION

In dynamic projects like green infrastructure, adaptive management is critical to the long-term success of these practices. Numerous factors can influence green infrastructure performance, including changes in plant growth, drainage areas, weather, and human activity, especially in urban areas. Most traditional gray infrastructure is designed to be static, and maintained at regularly scheduled intervals by municipal staff with particular skills and training. Green infrastructure may have different issues that arise, or unintended consequences of the design that need resolution. By closely observing these practices in the field, we can learn from experience to improve designs and better plan for maintenance.

Green infrastructure installations are diverse, and intentionally so. There is no one-size-fits all model, as design and performance are site-dependent. This can be a strength, especially in considering local hydrology and other site-specific priorities. However, it can also be a weakness, with higher up-front design costs (Green Nylan & Kiparsky 2015). Urban ecosystems in particular have many variables that are difficult to predict, both in physical conditions like disturbed soil and socio-political factors, and these site-specific conditions directly influence performance (Hopton et al. 2015).

Uncertainty about cost, performance, and maintenance are major barriers to more widespread adoption of green infrastructure (Green Nylan & Kiparsky 2015, Driscoll et al. 2015). Certain designs may be more maintenance-intensive, and therefore more expensive over the long-term. According to a survey of municipal officials from 23 communities implementing municipal green infrastructure plans, 79% agreed or strongly agreed that operations and maintenance issues were barriers to green infrastructure adoption (Driscoll et al. 2015). Adaptive management is also important, as managers may need to change maintenance schedules or forms of maintenance to ensure that practices continue to perform over time. Green infrastructure design improvements can help reduce long-term costs. While many factors are difficult to predict, clearer understanding of maintenance needs can inform more reasonable budgeting and performance expectations for projects. Municipalities in particular need this information for their budgets and staffing (Vail & Meyer 2013).

A better overall understanding of performance, particularly through place-based field research, can help improve cost-effective designs and reduce risk (Hopton et al. 2015, Green Nylan & Kiparsky 2015). This can help communities make better decisions about green infrastructure installation, which could also improve their performance (Hopton et al. 2015). Monitoring can be expensive and time-consuming, yet it is important to understand performance to meet regulatory requirements and other goals (Asleson et al. 2007a).

Information needs to be shared effectively for it to meet the needs of specific audiences, and we should think creatively about how to tell these stories and lessons learned in effective ways (Green Nylan & Kiparsky 2015). Visual observations of the overall site can provide important context for quantitative data, and be more useful for future decision-making (Green Nylan & Kiparsky 2015). Field observations can be very valuable, and a tiered approach to monitoring could help standardize information so it is more comparable (Green Nylan & Kiparsky 2015). The NYS DEC's maintenance guide for green infrastructure adopted this approach, with a hierarchy of assessment, especially since it can be cost-prohibitive for municipalities to hire specialists for routine evaluations of stormwater practices (NYS DEC 2017).

Several studies have evaluated a tiered approach to assessing green infrastructure, with visual observations as the first step. Asleson et al. (2009b) proposed a 4-tiered approach to assessing performance, with a Level 1 assessment as a visual assessment that focused on sediment accumulation, vegetation, and soil properties. In their case study, 4 out of 12 rain gardens failed the Level 1 assessment alone, which indicate that practices were not infiltrating properly (Asleson et al. 2009b). This indicated that a careful visual assessment provided sufficient information on problem locations and options for solving them, at a much lower cost than monitoring. Welker et al. (2013) proposed a tiered approach with 3 levels, including a visual assessment, hydrologic monitoring with a rain or staff gauge, and continuous monitoring. Lower level assessment still indicated if green infrastructure was functioning as intended, and was much better suited for municipalities that need cost-effective monitoring to meet requirements (Welker et al. 2013).

Observations can be particularly helpful for practices that do not have a clearly defined inlet or outlet to measure runoff or take grab samples to understand water quality dynamics. This was the case for the rain gardens, bioretention areas, and dry wells in Kingston's Uptown municipal parking lots included in this study. For practices designed to infiltrate stormwater without surface-level ponding, monitoring can be even more difficult. For example, the pervious pavers were not included in the quantitative assessment, even though they were designed to infiltrate the majority of runoff at the parking lot site (Barton & Loguidice 2015b).

Although these were not the first green infrastructure practices installed in Kingston, or even on City of Kingston property, the Uptown Kingston parking lot green infrastructure practices were unique in their visibility, scale, and maintenance by Kingston's Department of Public Works. The number and diversity of practices across a relatively small site was also unique. As such, they represented an excellent case study for visual observation as a tool to assess overall performance.

3.2 METHODS

Observations from frequent site visits (approximately every two weeks) were recorded between July 2016 (pre-construction) and July 2018 (2 years post-construction). Construction was completed on September 12, 2016 in the South parking lot and October 17, 2016 in the North parking lot. This 1.5 acre retrofit site included 2 rain gardens, 3 bioretention areas, 5 dry wells, and 3 sections of pervious pavement. (For more information on the site location, see Chapter 1: Introduction.) Results of the observations were categorized by drainage area, overall site design, in-practice, and winter maintenance.

The City of Kingston's Department of Public Works is responsible for maintaining municipal parking lots. They work with the Engineering department to monitor and inspect the lots each year, and make in-house repairs whenever feasible (City of Kingston 2013). Kingston's original grant application acknowledged that if the project did not meet the original goals after five years, Engineering Department staff would make recommendations to be implemented by the Department of Public Works (City of Kingston 2013).

3.3 RESULTS

Drainage Area

Asphalt Grading

Green infrastructure sizing and other design depends on the size and characteristics of the drainage area, and appropriate grading is critical to carry runoff into the practices. If post-construction grading differs from the design, practices may be receiving more or less stormwater than they were designed to receive. In the South parking lot, one dry well was graded at too steep an angle, and another was initially not low enough to collect water from its designed drainage area.

The grate of Dry Well South 2 was originally too far below the grade of the parking lot. Although this did not directly impact the drainage area for the green infrastructure practice, grading around the grate created a steep depression that was difficult for vehicles to clear. After the parking lot had been open about a month and a half, the City of Kingston raised the grate and asphalt around Dry Well South 2 about 3.5 inches, although the concrete cast portion of the dry well stayed in the same place (Figure 3.1). This was done around October 13, 2016. Raising it still allowed for stormwater to enter the dry well, but better protected vehicles.

Figure 3.1: Grading around Dry Well South 2. Originally grading was too steep (top, September 1, 2016), and the grate was raised about 3.5 inches (bottom, October 13, 2016).

In contrast, the grate of Dry Well South 1 was not low enough to receive runoff from its designed drainage area. After construction, stormwater was bypassing the dry well and flowing into Green Street's storm sewers (Figure 3.2). Stormwater from the southwest corner of the South parking lot was designed to flow into the conventional stormwater system on Green Street, without treatment by green infrastructure practices. However, the grading error resulted in stormwater from the drainage area intended for Dry Well South 1 to also flow in this direction. By May 20, 2017, the City of Kingston regraded the asphalt surrounding that dry well, allowing for substantially more water to be treated by the practice.

Figure 3.2: Grading around Dry Well South 1. Before regrading, stormwater was bypassing the grate and flowing west into Green Street (left, May 5, 2017). New grading allowed this practice to capture runoff from a much larger area of the parking lot (right, May 20, 2017).

The South lot contained one large section of pervious pavers, along with two strips of pavers between parking stalls. Although the pervious pavers between the eastern parking stalls received runoff from the surrounding asphalt, the western parking stalls were crowned (Figure 3.3). Although pervious pavers were used here, they are not likely to infiltrate runoff other than the rain that falls directly on them. They were not included in designs or calculations to reduce runoff, and appear to be a visual choice rather than serving as a stormwater management practice (Barton & Loguidice 2015b).

Figure 3.3: Crowned pervious paver strip between parking stalls in the South parking lot (September 2, 2016).

Potential for Clogging

Infiltration-based stormwater practices depend on pore spaces in soil to facilitate the movement of water downward. Fine sediment, organics, and other materials carried into the practice from the drainage area can clog these pathways and may compromise the green infrastructure's performance if they accumulate.

The pervious pavers and dry wells at this site had relatively large drainage areas within the two parking lots (45% and 36% of the parking lot area, respectively, Barton & Loguidice 2015b). To reduce the risk of clogging in pervious pavement, the *NYS Stormwater Management Design Manual* recommends that, “The contributing drainage area [to pervious pavement] should be limited to small adjacent impervious areas (i.e. non-traffic side walk and rooftop” (NYS DEC 2015). The Manual notes that pervious pavers in particular are prone to clogging when they receive runoff from other areas (NYS DEC 2015). The *NYS Stormwater Management Design Manual* also states that dry wells are also generally best-suited to treating rooftop runoff, and recommends some form of pre-treatment to reduce the risk of clogging (NYS DEC 2015). Especially since they are intended to infiltrate a large area of both parking lots, maintenance will be particularly important for proper drainage of the pervious pavers and dry wells.

A section of pervious pavement on the west side of the North parking lot appeared to be clogged as early as November 30, 2016, about a month after construction (Figure 3.4). Water ponded above the pavers after heavy rain, and debris between the pavers seemed to be blocking the water’s flowpath. Litter and plant debris contributed to the clogging. This issue grew worse over time, and eventually enough sediment collected for weeds to grow between the pavers. This section of pervious pavers was not functioning properly, and would need to be vacuumed and maintained.

Figure 3.4: Clogging in pervious pavers in the North parking lot over time. (Top, November 30, 2016; middle, February 11, 2018; bottom, June 20, 2018.)

The dry wells' large drainage areas included trees and other vegetation. Leaves from these trees collected on and in the dry wells (Figure 3.5). After two years, some of the gravel at the bottom of the dry wells appeared to be covered by material, and there were some weeds growing in the medium at the bottom (Figure 3.6). Leaf litter was observed in all of the dry wells except Dry Well South 3, which drains a much smaller area that doesn't include trees. This material may start to clog the gravel storage areas and reduce infiltration rates over time.

In the areas where the asphalt was regraded around Dry Well South 1 and 2, there appeared to be some degradation, resulting in fine particles forming along the edges and flowing into the dry wells. These fines could also contribute to clogging in the dry wells over time.

The bioretention areas and rain gardens have very small drainage areas (11% and 8% of the parking lot area, respectively, Barton & Loguidice 2015b). The potential for clogging in these areas was more related to in-practice erosion and mobilization of sediment (see below for more information).

Figure 3.5: Leaf litter and debris collecting on the grate of Dry Well South 2. (Top, September 21, 2016; bottom, October 24, 2017.)

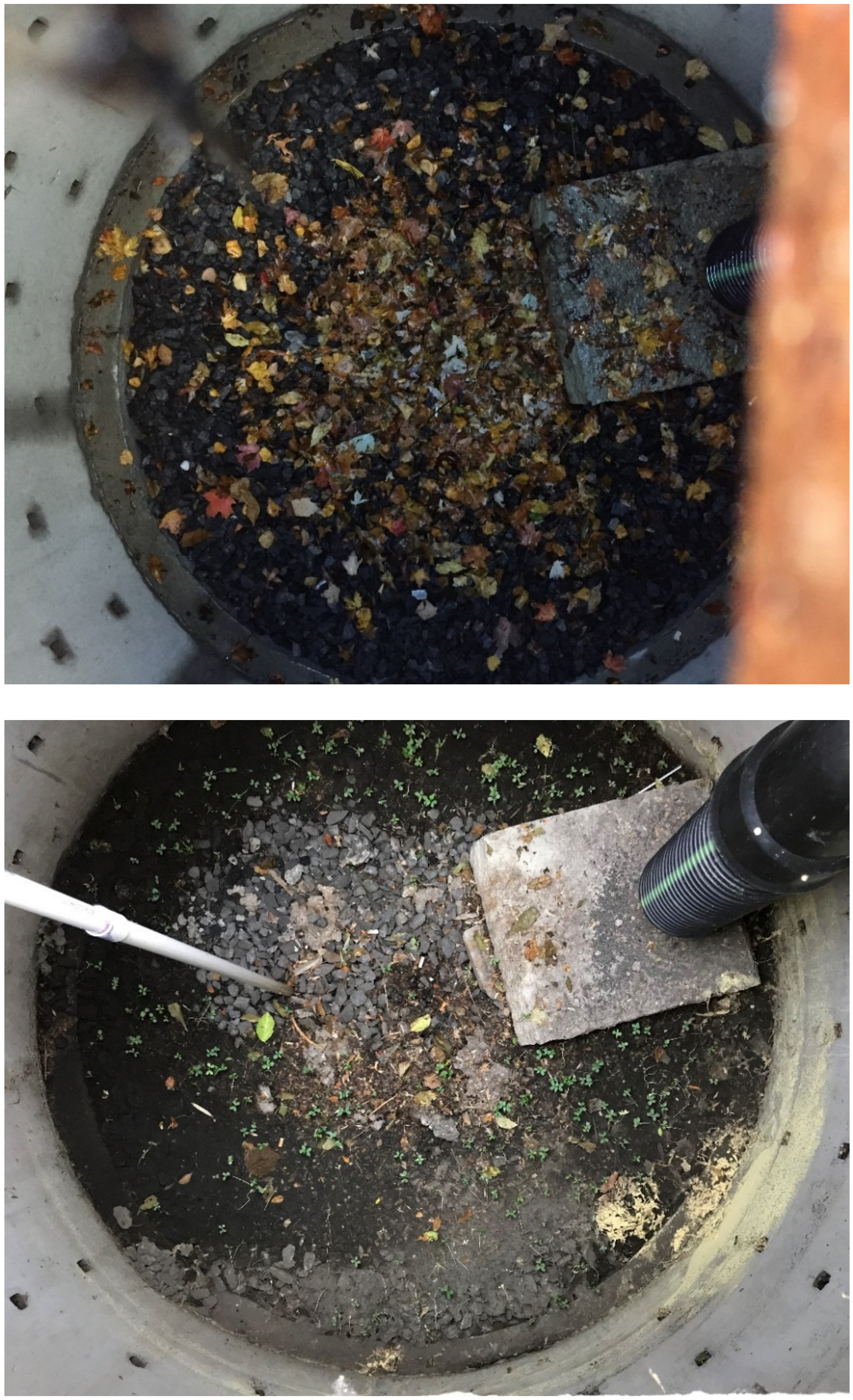

Figure 3.6: Debris at the bottom of Dry Well South 1. Leaf litter observed on October 28, 2016 (top) and plant growth observed on June 20, 2018 (bottom).

Litter

Litter was frequently observed throughout the parking lots and within the green infrastructure practices. Although there was briefly a trash can in the North parking lot, later there were no trash cans in either parking lot. Cigarette butts in between pervious pavers and other small pieces of trash contributed to clogging. The presence of needles (seen in a dry well) and bottles also speaks to other social issues that may be having an environmental impact.

Overall Site Design

Vehicular Transportation Flow

The new design of both parking lots changed the configuration of the entrances, parking spaces, and driving lanes within the lots. The North lot previously had two entrances, and one of those was replaced by Bioretention Area North. Several cars accidentally drove into and through this practice after construction (Figure 3.7). In addition to being a safety hazard, this could have compacted soil and compromised the bioretention area's performance. The entrance of the South lot remained the same, and cars did not appear to drive into the bioretention areas on this side. The South lot also originally had guardrails between the parking lot and the sidewalk, where the bioretention areas were located after construction (Figure 3.8).

Figure 3.7: Multiple sets of tire tracks, indicating people driving through Bioretention Area North on October 28, 2016 (top) and December 7, 2016 (bottom).

Figure 3.8: Guardrail in the South parking lot before construction (top and middle, July 18, 2016), where Bioretention Area South 2 was installed (bottom, June 20, 2017).

All of the rain gardens and bioretention areas were designed to receive sheetflow runoff from their entire perimeter, and as such, there was no curbing or physical barrier between the asphalt and the vegetation. Cones and construction fencing surrounded the bioretention areas in both parking lots for about three months after construction (Figure 3.9). By the end of December 2016 they were removed and replaced by metal fencing along the sidewalk side of the bioretention areas. These metal fences separated the bioretention areas from the sidewalk and roads to improve safety and prevent vehicles from crossing through the practices (Figure 3.10). The fences included reflective tape for better visibility at night. Installation of the fencing began in the South lot on December 28, 2016 and was completed for all three bioretention areas by January 6, 2017.

In the two rain gardens, cones were used to mark the edges of the practices for many more months after the construction fencing was removed. Rain Garden North had a guardrail between the parking stalls and the practice, which had been in place since before construction. A metal fence with reflective tape was later installed along the sidewalk side of Rain Garden South on February 24, 2017.

Figure 3.9: Caution tape up in Bioretention Area North (top, November 30, 2016) and construction fencing in Bioretention Area South 2 (bottom, December 17, 2016). The caution tape was removed in the first week of December 2016, and the construction fencing in all bioretention areas was removed by the end of the month.

Figure 3.10: Bioretention Area North before (top, October 26, 2016) and after (bottom, February 26, 2017) metal fences were installed.

With the exception of the guardrail along Rain Garden North, none of the vegetated practices had physical barriers on the parking lot side. It appeared that cars drove through the edges of the bioretention areas in both the North and South lot when turning within the parking lots (Figure 3.11). The re-design of the driving lanes required cars to take tight turns.

Figure 3.11: Tire tracks through the edge of Bioretention Area South 2, after fences were installed (January 22, 2017).

Although not designed to be green infrastructure, there were several areas of green space within the parking lots that that were intended to be planted with grass, perennial bulbs, daylilies, or other vegetation less than 30 inches tall (Barton & Loguidice 2015a). These areas were never planted, and instead were left as bare soil. Some of these areas filled in with weeds.

In the North lot, one of these areas that was intended to be vegetated was frequently used for parking (Figure 3.12). The curve of that particular driving lane was also sharply angled, and it appeared that some vehicles took the turn through the bare soil (Figure 3.13). This compacted the soil, and also mobilized sediment that was carried across the parking lot toward Dry Well North 1 and Pervious Pavers North 1. Due to the compacted soil and frequent disturbance, vegetation did not establish here.

Figure 3.12: Vehicles parked in an area of bare soil in the North lot that was designed to be vegetated. (Clockwise from top left: February 24, 2017; August 17, 2017; September 5, 2017; and September 28, 2017.)

Figure 3.13: Tire tracks through areas of bare soil in the North lot that were designed to be vegetated. (Top, April 9, 2017; bottom, February 24, 2017.)

The original designs for the parking lots included a bike rack in each of the parking lots, which were not installed (Barton & Loguidice 2015a). People did occasionally use the metal fences along the bioretention areas and Rain Garden South to lock bikes (Figure 3.14). There was also a large bike rack at the intersection of North Front Street and Wall Street, and people were more likely to lock bikes outside of their destination, rather than in the parking lot.

Figure 3.14: Bike locked to the fence along Bioretention North (October 9, 2017).

Pedestrian Transportation Flow

Although parking lots are generally designed primarily with cars in mind, pedestrian traffic flow is still an important consideration. People began walking through the edges of Bioretention Area North and Bioretention Area South 1 as soon as they were installed, as it was the most convenient way to get from the parking lot to the businesses in the Uptown neighborhood. According to the plans, these area were designed to be part of the stormwater practices (Barton & Loguidice 2015a). As people crossed through them, it compacted the soil and reduced the storage of those bioretention areas. Signs posted during construction were confusing, and seemed to indicate that pedestrians should be crossing through the edges of the bioretention areas (Figure 3.15).

These pathways resulted in an informal walkway through Bioretention Area North and South 1, which were used even in wet weather when the practices were muddy. After fencing was installed around the bioretention areas at the end of December 2016/beginning of January 2017, there was clearly space left for pedestrians to walk through at this location. The City of Kingston added gravel to make these walkways more formal in January 2017. Eventually, the gravel was carried with runoff into the bioretention areas. This issue was exacerbated in Bioretention South 1 by a downspout from an adjacent building that directed runoff across the gravel walkway and into the bioretention area (Figure 3.16).

Concrete pervious paver blocks were installed in both bioretention areas to improve the walkway during the first week of July 2017. This was done in the South lot during the first week of July 2017 and in the North lot during the second week of July 2017. At this time, the downspout directing runoff into Bioretention Area South 1 from an adjacent building was redirected into the parking lot and into the drainage area of Dry Well South 3. See Figures 3.17 and 3.18 for the progression of the walkways through Bioretention Area South 1 from informal to formal.

Figure 3.15: Sign in Bioretention North indicating that pedestrians should cross through the stormwater practice (November 7, 2016). The sign reads, “SIDEWALK CLOSED AHEAD CROSS HERE.” The sidewalk was also not closed at this time.

Figure 3.16: Erosion of gravel walkway into Bioretention Area South 1 (June 2, 2017).

Figure 3.17: Informal walkway through Bioretention Area South 1 on October 22, 2016 with construction fencing (top) and January 1, 2017 with metal fences (bottom).

Figure 3.18: Formalized walkway through Bioretention Area South 1 on January 6, 2017 with gravel (top) and on July 14, 2017 with pervious pavers (bottom).

In-Practice

Vegetation and Landscaping

The rain gardens and bioretention areas were first planted on October 13, 2016 after construction was completed in both lots. On May 26, 2017, a number of serviceberry shrubs were added to all of the bioretention areas and Rain Garden North. Each of the rain gardens and bioretention areas were planned to have native trees, shrubs, perennials, and ornamental grasses, with the exception of Rain Garden South (Barton & Loguidice 2015a). This practice was much smaller, and was planted with perennials and ornamental grasses (Barton & Loguidice 2015a). See Appendix E for the designed plantings for each rain garden and bioretention area.

The original designs called for all of the rain gardens and bioretention areas to have a 2 inch layer of mulch (Barton & Loguidice 2015a). However, only Bioretention Area North was mulched; this was added the first week of December 2017 (Figure 3.21). Bioretention Area North had much less weed growth than the other vegetated practices, and the mulch seemed effective in holding moisture and limiting weed growth.

Figure 3.19: Initial planting in (clockwise from top) Bioretention Area South 2, Bioretention Area North 1, and Rain Garden South (October 13, 2016).

Figure 3.20: Serviceberry plantings in (clockwise from top left) Bioretention Area North 1, Rain Garden North, Bioretention South 2, and Bioretention Area South 1 (May 26, 2017).

Figure 3.21: Mulch in Bioretention Area North when it was first added (left, December 7, 2016), and with some weed growth during the first summer (right, August 17, 2017).

The first maintenance of vegetation was mowing in Bioretention Areas South 1 and South 2 around August 4, 2017. Bioretention Area North did not appear to be mowed, as the mulch had largely kept weed growth down. The rain gardens were not initially mowed, and were increasingly filled with weeds. These eventually were mowed by the end of September 2017, and all of the vegetated practices were mowed periodically since then. Mowing damaged some of the planted woody vegetation (Figure 3.22). The rain gardens and bioretention areas were also used for snow storage during the winter, and some of the shrubs were damaged with the force of the snow being plowed directly into the vegetation (Figure 3.23).

Native plants in green infrastructure practices can provide benefits for wildlife. The berries from serviceberry shrubs provided food for birds and other animals, which is especially beneficial in urban environments (Figure 3.24).

Compared to other vegetated green infrastructure practices, the rain gardens and bioretention areas were initially not densely planted. Vegetation also thinned over time, especially in the three bioretention areas, which were mowed more frequently than the rain gardens. As of June 2018, most of the original native plantings were gone, with the exception of a few larger serviceberry bushes (Figure 3.25). The vegetation that survived the first winter and mowing seemed to be doing well.

Figure 3.22: Damage from mowing to serviceberry shrub in bioretention area (September 13, 2017).

Figure 3.23: Vegetation damage from winter plowing in Bioretention Area South 2 (January 29, 2018).

Figure 3.24: Serviceberries in Bioretention Area South 2 (June 16, 2017).

Figure 3.25: Progression of mowing and maintenance on vegetation in Bioretention Area South 2. Photos are from July 28, 2017 (top left), August 4, 2017 (top right), August 24, 2017 (bottom left), and September 13, 2017 (bottom right).

Surface of Practices

In addition to the flow of runoff from contributing drainage areas, the flow of water within the practice can also impact performance. Although many green infrastructure practices are designed with a forebay to slow the velocity of runoff entering the practice, reduce erosion, and allow sediment to settle out, none of these practices were designed with a forebay. All of the vegetated practices were also designed without curbing, which allowed sheetflow to enter the practice from any direction, without a discrete inlet.

Stormwater entering the practices appeared to contribute to erosion. The sides of Bioretention Area South 2 and Rain Garden South were steep and initially appeared to be eroding, with small rills forming (Figure 3.26). This may have mobilized sediment and moved it to the bottom of the practice, especially as the practices lacked mulch or dense vegetation to help stabilize the slopes. The side of Bioretention Area South 1 in particular was very steep, but later appeared to have stabilized at a gentler slope (Figure 3.27). There may have been some subsidence in the practices, as Rain Garden South in particular appeared to have grown deeper. This may have been from the soil settling, or the weight of the snow that was plowed into the practices.

Erosion along the edges of the vegetated practices may have contributed to damage on the hardscape surfaces around them. Bricks that lined the sidewalk adjacent to both Bioretention Area South 2 and Rain Garden South noticeably fell into the practices, and the sidewalks were not repaired (Figure 3.28). The asphalt near Rain Garden South cracked slightly near the practice, which could lead to structural damage over time; the asphalt along Rain Garden North was also deteriorating (Figure 3.29).

Figure 3.26: Rills initially formed after construction and before planting along the edge of Bioretention Area South 2 (left, October 5, 2016) and Rain Garden South (right, September 12, 2016, photo by Beth Roessler).

Figure 3.27: Steep side slows in Bioretention Area South 1 (February 22, 2017).

Figure 3.28: Bricks from the sidewalks falling into Bioretention Area South 2 (top, April 27, 2017) and Rain Garden South (bottom, April 9, 2018).

Figure 3.29: Asphalt cracking along Rain Garden South (left, April 9, 2018) and Rain Garden North (right) on the side opposite of the parking lot. Cracking worsened around Rain Garden South over time, and could cause structural damage.

The dry wells had stone splash pads to dissipate energy under the connecting underdrains, which were designed to serve as overflow for the pervious pavers and bioretention areas (Figure 3.30). It did not appear that water levels were high enough to have water be transported between practices. (For more information on water level in practices, see Chapter 2: Quantitative Assessment of Green Infrastructure.) These overflow pipes were perforated. Even if water levels were high enough to enter the overflow pipes, given the rapid infiltration across the site, water could infiltrate before it reached another practice. The splash pads in the dry wells could still dissipate energy from runoff flowing directly into those practices, although in-practice erosion is less of a concern with the gravel bottom.

Figure 3.30: Splash pads in Dry Well South 2 (September 2, 2016).

The bottom surface of infiltration practices should be flat to promote infiltration evenly across the surface (NYS DEC 2015). The bottoms of the bioretention practices were not flat, and ponding was deeper in certain areas (Figure 3.31). Although these green infrastructure practices appeared to infiltrate all of the runoff that was directed towards them, they were not using their full surface area for infiltration. This could also be concentrating fine sediment in certain parts of the bioretention area, which could impact performance over time. Bioretention Areas South 1 and South 2 had a layer of clay-y sediment on the surface, which was especially pronounced in dry weather (Figure 3.32).

Figure 3.31: Deeper ponding on one side of Bioretention South 1, indicating that the bottom surface is not flat (April 6, 2017).

Figure 3.32: Surface of Bioretention South, with a layer of fine clay-y sediment forming (May 20, 2017).

Practice Storage

All of the vegetated practices were designed to be depressed and offer physical storage for water to pond (Barton & Loguidice 2015a). However, most of the storage in Bioretention North was filled in with mulch. Over time the surface of the practice was slightly downslope from the sidewalk, but essentially level with the parking lot (Figure 3.33).

Figure 3.33: Ponding in Bioretention North before mulch (left, November 30, 2016). Over time, the practice became mostly flat, without a real depression for storage (right, August 28, 2017).

The overflow risers for all of the bioretention areas were also supposed to be 6 inches above the surface, per NYS Stormwater Management Design Manual specifications (Barton & Loguidice 2015, NYS DEC 2015). However, none of the overflow risers had a full 6-inch clearance. One of the two risers in Bioretention North in particular was located at the same level as the surface, which did not provide the full design storage. Despite this, Bioretention North still seemed able to treat the volume of runoff it received. (For more information on runoff reduction, see Chapter 1: Quantitative Assessment of Green Infrastructure.)

Concrete blocks were placed within two of the bioretention areas when the City of Kingston installed a new parking meter system. The first concrete block was installed on May 26, 2017 in Bioretention Area South 1; this was removed and replaced by a new concrete base by August 28, 2017 when parking meters were installed (Figure 3.34). The concrete block in Bioretention Area North was placed by June 2, 2017. Although these concrete blocks were small, they did slightly reduce the storage area in Bioretention North 1 and Bioretention South 1 and disturb the soil within the practices. The walkways for pedestrians to cross through the bioretention areas also reduced practice storage, as previously discussed. The location of the parking meters also impacted the flow of pedestrian traffic, as people would have to stop by the meters to pay for parking before proceeding to the businesses.

Figure 3.34: Concrete blocks placed within Bioretention Area South 1 for a new parking meter. The original location for the meter was moved (top, August 17, 2017) to a location along the sidewalk (bottom, August 28, 2017), leaving a disturbed area with bare soil in the bioretention area.

Winter Maintenance

Both the North and South parking lots are used for City of Kingston snow emergency parking. A snow emergency is declared in Kingston when over 4 inches of snow falls, and residents are allowed to park in the Uptown municipal parking lots while streets and other parking lots are cleared (Figure 3.35). Kingston's Department of Public Works plows these parking lots after all the streets and the other parking lots; since these are some of the last places that are plowed, there is a heavy use of de-icing road salt to help remove snow and ice (Figures 3.36). This salt could have an impact on vegetation within the practices over time, or impact groundwater quality.

Figure 3.35: Salt spreading truck in the North parking lot after a snow emergency was declared in Kingston (February 9, 2017).

Figure 3.36: Rock salt on pervious pavers in the South parking lot (February 22, 2017).

Snow was plowed toward the edges of the lots, and the bioretention areas and rain gardens provided a convenient storage location (Figure 3.37). Most of the snow from the South lot was pushed within the drainage area of Dry Well South 2, which treated a substantial amount of snowmelt (Figure 3.38). The woody vegetation in the bioretention areas was damaged from snow plowing, as previously discussed. Using the green infrastructure practices for snow storage reduced the area available to store runoff, particularly during rain-on-snow events (Figure 3.39).

Figure 3.37: Snow piled up in Bioretention South 2 (March 16, 2017).

Figure 3.38: Snowmelt into Dry Well South 2 (February 9, 2018).

Figure 3.39: Rain Garden South during a rain-on-snow event (February 11, 2018).

3.4. DISCUSSION

Although monitoring is important to understand green infrastructure performance, in this study, visual observation told a much richer and more comprehensive story than the quantitative data alone. Water level data provides high-resolution information on infiltration, but not necessarily on the mechanisms or reasons behind the results. The overall site also provides context for the performance of individual practices, and visual assessments can identify a problem's cause to better target specific maintenance tasks or other solutions (Asleson et al. 2007a). Although the practices in Kingston's Uptown municipal parking lots reduced runoff effectively, their performance could be compromised over time by the design and maintenance issues identified.

In general, there needs to be a clear plan for maintenance of green infrastructure, especially since practices can be so site-specific (NYS DEC 2017). The consulting engineers did not provide maintenance guidance to the City of Kingston, which is an important step. It is recommended that in the future, green infrastructure projects should budget finances and time to ensure that the project designers develop and explain the maintenance plan to the site owner and maintainer. The maintenance staff on the ground were several steps removed from the design process, and might not realize the impacts of their on-site decisions, like excessive mowing. Municipal staff will need training and education about the specific maintenance needs of green infrastructure practices. Municipalities may also consider hiring new positions that specialize in the types of maintenance that green infrastructure practices uniquely require.

One of the primary aspects of NYS DEC's green infrastructure maintenance checklist is the amount of time that standing water is visible after a storm. Although the *NYS Stormwater Management Design Manual* requires a maximum ponding time of 48 hours, the maintenance guidance recommends that action be taken if standing water is visible on the surface for more than 72 hours (NYS DEC 2015, NYS DEC 2017). This was not a problem for any of the green infrastructure practices in this study, as they all infiltrated much faster than that threshold. This was observed visually, in addition to being recorded as water level data by the HOBOs. The maximum time for a practice to infiltrate was 65 hours, in Rain Garden South, when a second storm came through before the first storm had fully infiltrated. (For more information on water level in the green infrastructure practices, see Chapter 2: Quantitative Assessment of Green Infrastructure.)

Even though green infrastructure can provide a number of benefits, it is unreasonable to expect that all practices could provide all benefits all the time. By establishing priorities for green infrastructure, sites can be designed and maintained more appropriately to meet those specific needs. This would help reduce areas of conflict, such as was observed in the bioretention areas.

The bioretention areas were located along the edge of the parking lots, between the parking lot and the North Front Street sidewalk. Although the engineering drawings were straightforward, in reality this was an area upon which many demands were placed. The bioretention areas were designed to provide storage space for stormwater and have vegetation; fencing, a pedestrian walkway, and a parking meter were added to the practices. Vehicles drove through the edges of the bioretention areas when turning within the parking lots, or attempted to drive through them when the entrances were changed. Pedestrians crossed through bioretention areas on their way to Uptown businesses. Snow was plowed to these edges, damaging vegetation. Parking meters were also installed within the practices' storage space. Litter from the parking lots also accumulation within the bioretention areas. Figure 3.40 demonstrates the conflicts of various uses in Bioretention Area North, as an example. The bioretention areas were still able to infiltrate stormwater runoff, despite the compaction and reduction in storage area. (For more information on water level in the bioretention areas, see Chapter 2: Quantitative Assessment of Green Infrastructure.)

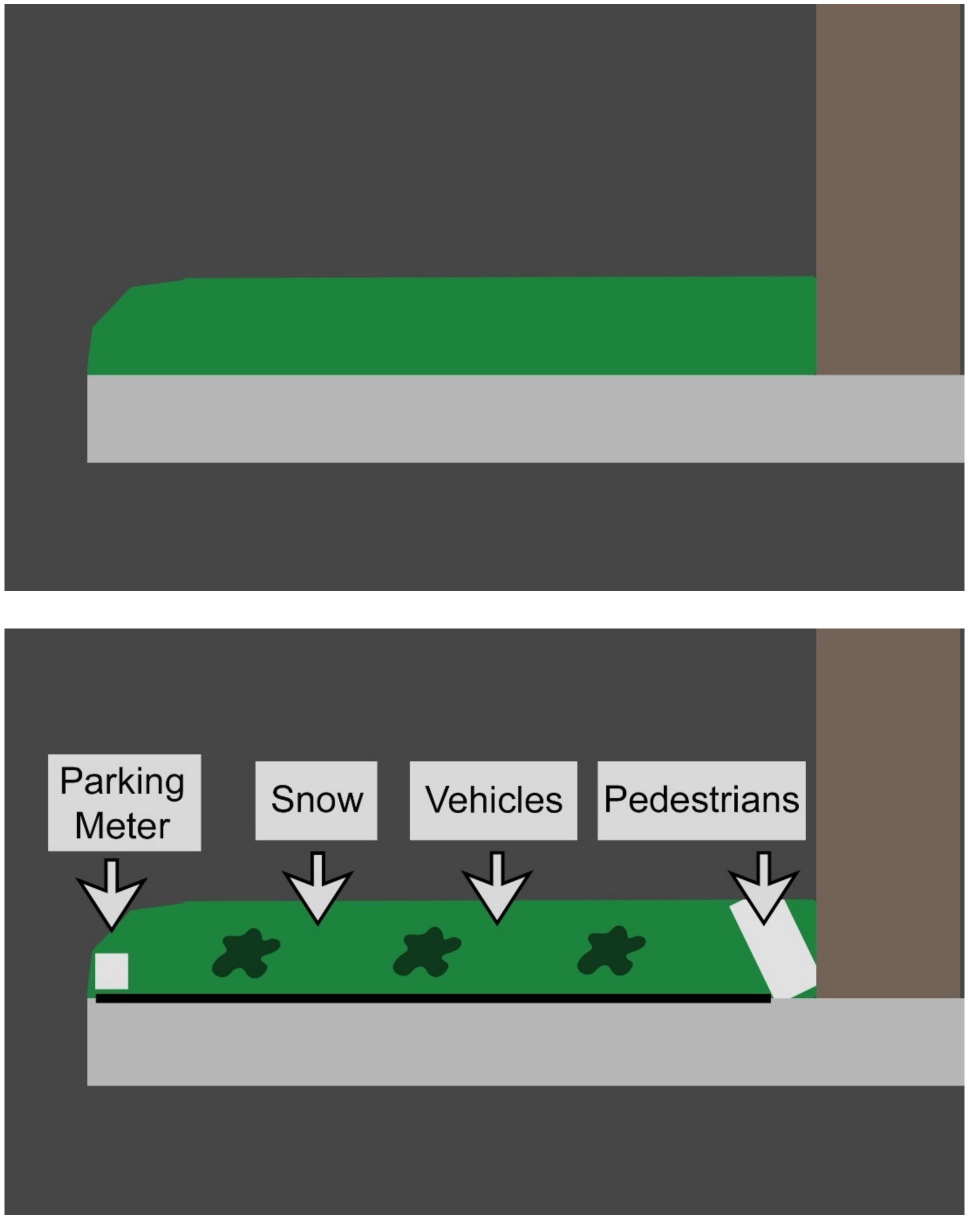

Figure 3:40: Diagram of conflicting uses of the bioretention areas. This shows a plan view of Bioretention North as an example. Although the engineering drawings were straightforward, and included a large storage area (top), in reality, this location had a number of conflicting demands (bottom). The green represents the bioretention area (with dark green vegetation), dark gray is the road and parking lot, light gray is the sidewalk, and brown is the adjacent building.

Based on the actions taken by the City of Kingston (especially installing walkways and parking meters), the parking lots' function as a parking lot was the top priority, and infiltration benefits of the green infrastructure practices were secondary.

Other priorities that could have informed design were more difficult to identify. If the priority were to have a location to pile snow, low-growing, non-woody stemmed vegetation could be planted in the bioretention areas to handle that use. If the priority were landscaping, denser plantings could be used, and snow could be piled elsewhere. There are trade-offs to each of these scenarios, and these should be examined during the design process. Urban spaces that include green infrastructure practices serve several purposes, and designers should be mindful of multi-tasking scenarios that may be contradictory.

The large drainage areas for the pervious pavers and dry wells resulted in significant amounts of material (organic debris, sediment, trash, etc.) coming into those practices, potentially clogging them. Based on NYS DEC's hierarchy of maintenance, the dirt and grit accumulated in the pervious pavers rose to a Level 2 (NYS DEC 2017). NYS DEC's maintenance manual recommends routine sweeping of pervious pavement with a regenerative air vacuum, particularly in the spring after winter maintenance or in the fall if the drainage area includes trees (NYS DEC 2017). Although the clogging of the pervious pavers did not appear extensive enough to fully prevent infiltration, it could worsen over time. Two years after construction, the pervious pavers had not been vacuumed or maintained.

Although the dry wells also had sediment accumulate, it did not appear to be compromising their performance. The leaf litter in particular seems to be contributing to the material accumulating at the bottom of the dry wells. Although urban trees are beneficial, the impact of their leaves on infiltration should be considered in green infrastructure design. According to City of Kingston's Department of Public Works, the dry wells will eventually be vacuumed out, but they will have to be careful not to remove the gravel (Boyle, personal communication, May 23, 2018). The sediment in dry wells was not significant enough yet to rise to a Level 2 problem (NYS DEC 2017). Since stormwater infiltrated very rapidly in the dry wells, sediment accumulation and slower infiltration rates may not be a problem for some time.

The bare soil area in the North parking lot was a high priority issue to resolve. Sediment from this area traveled directly into the North parking lot dry wells and pervious pavement, and the illegal parking there was not enforced. The City of Kingston eventually placed a large planter box on top of the bare soil to add vegetation and dissuade people from parking there. This planter contained vegetation, and was similar to what had previously been near the entrance of the North parking lot before construction (Figure 1.4). Although similar landscaping features were located throughout the neighborhood, this planter box looked out of place at the back of the parking lot, within an irregularly shaped patch of bare soil.

In the future, the City of Kingston may consider designing dry wells or pervious pavement with smaller drainage areas to reduce maintenance costs. Bioretention areas could be used to treat larger areas of the parking lot based on their sizing. Since they are located at the surface level, rather than 10 feet below the surface like the dry wells, their maintenance could be easier. Even though the bioretention areas store and infiltrate a smaller amount of runoff than the dry wells, the trade-off in ease of maintenance could be worthwhile to consider.

Dry wells are unique in that they are infiltration practices that look, from the surface, like traditional gray infrastructure. Although they don’t improve aesthetics, one of their advantages is that they do not take up space on the surface of the parking lot. They also look like a "normal" parking lot, which people are more used to seeing. Dry wells could be an efficient choice as a stormwater retrofit in cities where space is a constraint.

Parking lot design should be mindful of vehicular traffic flow and pedestrians, especially in urban areas. Urban design needs to include people, not just vehicles or stormwater. Pedestrians need a clear, safe, and direct place to walk, and it should be clearly understood by all users; there could be safety hazards if this is not the case. If green infrastructure practices are in the way of the most direct path for pedestrians, it may compromise their performance. Walkways, parking meters, or other additions can reduce storage capacity within the stormwater practices.

In addition to the design, there are other opportunities to help inform drivers and pedestrians, and maintain the parking lots' functions. Improved signage during or after construction could indicate the changes in the parking lots that residents' need to know. Parking enforcement also could have ticketed the vehicles that were illegally parked on the bare soil that was intended to be vegetated, which could have reinforced appropriate use.

Social dynamics also impact parking lot design and use. In July 2017, these municipal parking lots were converted to a paid meter system. This was a controversial issue for businesses in Uptown Kingston. The parking meters changed the flow of pedestrians through the lots, as people walked to the meters before going to the businesses, rather than taking the walkways along the bioretention areas.

Within the bioretention areas and rain gardens, the lack of mulch, thin plantings, and bare soil resulted in muddy puddles during storm events. Without mulch or dense plantings, the planted green infrastructure practices did not look like typical landscaping features. It appeared increasingly difficult for maintenance crews to identify which plants were intentionally part of the design, and which were weeds. Although the low grass that resulted after frequent mowing looked more typical, it didn't have the same benefits as native vegetation. The trade-off between easy maintenance (like lawns) and native vegetation is one that should be considered.

Steep slopes within the vegetated practices can result in erosion, but also supports lateral exfiltration of stormwater. For long and thin bioretention areas with a high proportion of side-walls, lateral exfiltration has been shown to be a dominant pathway for volume reduction of stormwater (Winston et al. 2016). This was the shape of all the bioretention areas and Rain Garden North in this study. Lateral exfiltration could have cumulative results if many small-scale green infrastructure practices were constructed within a watershed (Winston et al. 2016). If practices have significant side-walls, mulch or denser planting of vegetation may help hold the soil and reduce erosion within the practices.

The dry wells were also designed to have lateral exfiltration through the sides of the concrete structure, although it did not appear that water level rose high enough to take advantage of this pathway (see Chapter 2: Quantitative Assessment of Green Infrastructure).

It may also be helpful to dissipate energy from the stormwater entering the vegetated practices, especially if it comes from a particular direction and there is substantial erosion. This seemed like an issue in Rain Garden South, which could use stabilization on the corner where most runoff enters, along the sidewalk. There was also cracking asphalt around Rain Garden South, which could lead to structural problems over time.

Within the practices, it may be helpful to re-grade the bottom surface of the bioretention areas so the bottoms of practices are flatter. This would promote more even infiltration across the practice. If the crusty, hard-pan-like layer within the bioretention areas persists, it should be removed, as it could slow infiltration (NYS DEC 2017). No animal burrows or unauthorized plantings were observed, and there did not appear to be sediment accumulating in the underdrains of the bioretention areas (NYS DEC 2017).

Based on DEC's maintenance guidance, vegetation issues and possibly sediment accumulation in bioretention areas and rain gardens would rise to a Level 2 (NYS DEC 2017). This could be resolved with mulch and denser vegetation, if the sediment is from in-practice erosion. Vegetation tolerant of heavy snow and the impact of snow plowing should also be considered. Maintenance crews should also take care to avoid damaging native vegetation as they are removing weeds.

The heavy application of road salt for winter weather could impact the vegetation or groundwater quality, as salty runoff travels from the practices directly into groundwater. Given the large capacity of dry wells, along with their lack of vegetation, snow could be plowed to the edges of the parking lot into the drainage areas for dry wells, rather than into the bioretention areas. The issue of snow plowing damaging vegetation was not resolved within the first two years after construction.

Practices in general did not seem to be aesthetically pleasing, and the parking lots did not appear well cared-for. Trash throughout the parking lots reduced aesthetic appeal, and there was a clear need for improved waste management. Bricks from the sidewalks fell into the practices, particularly Bioretention Area South 2 and Rain Garden South. The sidewalks were not repaired during the two years of observations, and the bricks were not removed from the practices. The caution tape and cones were up for months after construction, and they were not attractive or effective in keeping vehicles out of the practices. These gave the appearance of the lots as an active construction site, even long after construction was completed.

The aesthetic appeal of green infrastructure is one of its main selling points, especially as an advantage over traditional gray infrastructure. Care should be taken to keep practices looking attractive. This is especially important in dense urban areas, where practices are highly-visible and space is precious. The aesthetics of green infrastructure practices should be high priority, along with their ability to reduce runoff. Even pervious pavement, which is a “grayer” form of green infrastructure, does not look attractive if it is not maintained. There are many ways to have green infrastructure practices look attractive and cared for, and this should be a key feature of the design and maintenance.

On the other hand, these two parking lots have benefitted from public art. As part of Kingston’s O+ Festival, two large murals were painted on buildings alongside the parking lots. A third is visible across the street. These murals have been painted throughout Uptown Kingston, and in the Uptown municipal parking lots, they add color and visual appeal.

There may be other opportunities to improve stormwater management through green infrastructure retrofits throughout Uptown Kingston. Despite the density of development in this neighborhood, there are many large planters and other landscaping features (Figure 3.41). This area is well-suited to infiltration due to its sandy, well-drained soils and high depth to groundwater. This is also an important business district, and could benefit from additional vegetation. Many downspouts from the building roofs and canopies discharge directly into the sidewalk or street, and these could be redirected into green infrastructure practices, such as stormwater planters.

Figure 3.41: Large planter box on Wall Street with an adjacent downspout that discharges directly onto the sidewalk (April 19, 2017). This type of site could be an opportunity for future green infrastructure retrofits.

3.5 CONCLUSIONS

Close visual observations of green infrastructure in the field can provide important lessons learned on both design and maintenance. Certain aspects of green infrastructure performance are difficult to predict, and there are many complex factors at work in urban environments. It is important to have adaptive management to make adjustments as needed, once the practices are in the ground, to ensure good performance over time. Observed issues for maintenance could also inform green infrastructure design in the future.

Frequent visual observations of the site provided feedback on the green infrastructure practices that otherwise would have been difficult to obtain. The NYS DEC's green infrastructure maintenance manual recommends a basic, level 1 inspection at least annually, supplemented by observations after large storms or seasonal changes to detect potential issues before they become larger and more difficult to resolve (NYS DEC 2017). An annual visit would not be high-resolution enough to observe the issues identified by more frequent observations (approximately every 2 weeks in this study). Seasonal inspections may be more appropriate, including visits during storm events, with more frequent observations directly after construction.

After construction, the City of Kingston made several changes to improve the parking lots and drainage, while other issues still remained. Based on these observations, there are several recommendations for these parking lots, as well as recommendations for green infrastructure practice design and maintenance in general. For specific recommendations to the City of Kingston based on this study, see Appendix F.

This study also provided valuable information for other municipalities or stakeholders considering green infrastructure retrofits in pubic urban spaces. Given the scale and anticipated timing of changes, this observational data was very high-resolution and made for an excellent case study. These practical “lessons learned” represent the type of information that municipalities need to make better decisions about planning and implementing green infrastructure (Vail & Meyer 2013, Green Nylan & Kiparsky 2015).

Many case studies only include photos of the practices immediately after construction, before any changes in plant growth, maintenance, or actual use of the site. By showing other pictures of green infrastructure practices over time, including in a variety of weather conditions and when they don’t necessarily look as attractive as they could, we can learn much more about their actual management. It is important to identify opportunities for improvements. Over time, decisions about maintenance could compromise the practices, and if municipalities don’t understand what went wrong, they may decide that green infrastructure is not worthwhile for future projects.

Green infrastructure in cities is not just a technical engineering problem. There are many trade-offs to consider that impact green infrastructure design. Storage space, winter maintenance, plant selection, and even practice selection could depend on specific priorities for a specific site. Green infrastructure practices are designed to be unique, and they should be designed to meet the particular needs at a site. Broader scale priorities should also be considered, such as the needs of the watershed, neighborhood, or municipality. In addition to the technical designs for green infrastructure, other factors include the overall site design, signage, plant selection, parking enforcement, waste management, and education for municipal maintenance staff. Green infrastructure represents an opportunity to rethink urban stormwater management, and a broader application of these practices could improve water quality and flooding in a meaningful way.

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CHAPTER 4

TRACING THE TANNERY BROOK

4.1 INTRODUCTION

The Tannery Brook is a small stream in Kingston, NY. Although the Tannery Brook has worked hard for Kingston over the centuries – including powering mills, irrigating crops, and carrying away waste – it has been increasingly fragmented and forgotten. Several sections have been buried underground, and its headwaters have been redirected towards a different stream. It has not been forgotten by everyone, though, as it continues to make its presence known through flooding, infrastructure failure, and other issues.

The two municipal parking lots on North Front Street are within the Tannery Brook's watershed. Prior to the construction of green infrastructure practices, stormwater in the South parking lot was directly connected to the buried portion of the Tannery Brook via storm sewers that traveled along North Front Street to the intersection of Green Street and Frog Alley. Although the North parking lot did not have storm sewers, the majority of runoff traveled toward the back of the parking lot and down a steep slope, into a parking lot with a storm drain that likely connected to the Tannery Brook underground. (For more information and photos of pre-construction conditions, see Chapter 1: Introduction).

After green infrastructure practices were installed, the stormwater from both parking lots infiltrated fully into groundwater, disconnecting this 1.5 acre impervious area from the storm sewer system. Although this portion of the study began as an attempt to understand pre- vs. post-construction stormwater fate, it expanded to a much broader study of the history of the watershed. This allows for a placing of green infrastructure within the broader temporal and spatial contexts, across the watershed's history. In particular, this study examines the Tannery Brook's watershed over 350 years of water management decisions.

A longer-term assessment of urban streams can provide new and different insights into their current-day management. Kaushal & Belt (2012) propose "the urban watershed continuum" as a conceptual framework to understand the complex dynamics and stressors faced by urban streams. Urban streams include four key dimensions: longitudinal (stormdrains have replaced headwater streams, but still function in a similar way), lateral (urban streams are disconnected from riparian zones and floodplains, but have greater hydrologic connectivity through the stormdain network), vertical (groundwater and surface water connections), and temporal (both short-term processes like individual storms and long-term processes like aging infrastructure and development changes, Kaushal & Belt 2012). Kaushal & Belt (2012) cite the need for a long-term research perspective to connect urban infrastructure, ecosystem restoration, and long-term changes in water quality and quantity. Marcucci (2000) also recommends understanding a landscape's history as an approach to modern environmental planning, and acknowledged that method to study a landscape's temporal context are not well understood.

Small headwater streams can represent over two-thirds of total stream length in a typical watershed (Freeman et al. 2007). Cumulatively, small streams can have a large impact on nutrient dynamics, in-stream secondary productivity, and habitat

(Freeman et al. 2007). Even small urban streams have the potential to improve water quality and provide habitat for fish, amphibians, invertebrates, and other wildlife (Trice 2013). Ephemeral streams can make significant contributions to water quality improvements by transforming nutrients, especially through contact with sediment in the stream channel (Trice 2013). Disconnecting streams from their banks and riparian areas disrupts these functions, impacting habitat and water quality within these streams and downstream (Trice 2013). Even small streams can have a big impact, although they suffer from a lack of visibility (Trice 2013).

Most first order streams in cities have been replaced by infrastructure; one study found that 73% of streams in Baltimore had been buried (Elmore & Kaushal 2008, Kaushal & Belt 2012). Incorporating headwater streams and their contributing baseflow into the stormwater system increases drainage density and drastically alters the physical form of urban streams (Kaushal & Belt 2012). Interbasin transfers are common in cities, and complicated networks of pipes add complexity to groundwater dynamics (Kaushal & Belt 2012).

Although urban streams have been notorious for causing flooding problems, they also have the potential to improve water flows and help with climate resiliency. Burying streams does not solve flooding problems, but rather moves them downstream or to different areas (Trice 2013). Undersized culverts where roads cross over streams, or streams are buried, may also contribute to urban flooding (Trice 2013).

There is a need for a most holistic approach to flooding, and an appropriate place for storm and flood waters to go. Improvements in one area should not lead to adverse impacts in another. Increasingly, rivers or streams are recognized as assets that can provide aesthetic value or recreational opportunities (Trice 2013). Today, we need a better understanding of urban stream systems so they can be protected or improved.

The Tannery Brook is a microcosm of the ways that we manage and relate water in cities. Although the Tannery Brook is a small stream, it has had a big impact on Kingston, and continues to affect the community today. At only 1.5 miles long, with a watershed of approximately 1.4 square miles, it is also a manageable scale for an extensive historical study. This detailed, highly local analysis can provide broadly applicable insights on trends and decision-making around water in cities.

This study examined the history of the Tannery Brook through 4 major themes over time:

- Ecosystem services provided,
- Geomorphology,
- The process of fragmentation, and
- Land use changes within its watershed.

Understanding the watershed and stream history can put “restoration” practices like green infrastructure into context, and allow us to consider what baseline or level of stream health might be reasonable to expect. Sharing the Tannery Brook's story allows for a better understanding urban streams and what it might take to improve them in the future.

4.2 METHODS

I gathered historic maps, historic images, local history narratives, newspaper articles, and other original documents to learn more about the Tannery Brook and water management in Kingston. These materials either directly discussed the Tannery

Brook or provided context for conditions or decisions that would have impacted it. Although it is difficult to gather sources of data on landscape or watershed history, as there is no one central location for this information, various documents or field evidence can be pieced together (Marcucci 2000). Maps in particular provided valuable information for this project. Maps that included the Tannery Brook were intended for various purposes, including wayfinding, establishing property boundaries, and proposing engineering projects. Historic materials came from a variety of sources, including the City of Kingston, Ulster County archives, New York State Library, Senate House State Historic Site, Friends of Historic Kingston, and Cornell University Map & Geospatial Information Collection.

Jiamin (Jasmine) Chen, a graduate landscape architecture student from Cornell University, collaborated on this research by creating a series of digitized maps based on historic maps. The digitized maps visualized changes in and around the Tannery Brook with a consistent set of symbology for easier comparison over time. Jasmine matched each historic map to a base map using roads and other features from the time, and traced important content (such as land use, property boundaries, buildings, and uses of the stream) in Adobe Illustrator. Many of the digitized maps include a best assumption of where streams would be at the time, if they were not fully mapped on the original map. In some cases multiple maps were juxtaposed to show a broader, watershed perspective on the Tannery Brook.

4.3 RESULTS – TANNERY BROOK HISTORY

Location

The Tannery Brook is located in Kingston's Uptown neighborhood. It flows out of the Twin Ponds, travels downhill along Linderman Avenue, crosses under Washington Avenue, skirts property lines between Washington Avenue and Green Street, and then vanishes beneath the parking lot behind the Ulster County Family Court building (Figure 4.1). It makes the rest of its journey underground, in a pipe, until it meets the Esopus Creek behind Kingston Plaza (Figure 4.2). Part of the Tannery Brook (about 0.7 miles from Twin Ponds to Washington Avenue) is diverted to the Twaalfskill, which runs along Wilbur Avenue into the Rondout Creek (Milone & MacBroom 2015). The Tannery Brook's main tributary is the Main Street Brook, which travels downhill along part of Main Street west of Washington Avenue. The Main Street Brook joins the Tannery Brook underground, near Lucas Avenue.

The Tannery Brook is approximately 2 miles long, and based on a topographic delineation, its watershed drains approximately 1.4 square miles of urban and suburban development (Figure 4.3, Heady 2014, U.S. Geological Survey 2018).

For historical maps, paintings, photos, and other materials of the Tannery Brook, see Appendix G.

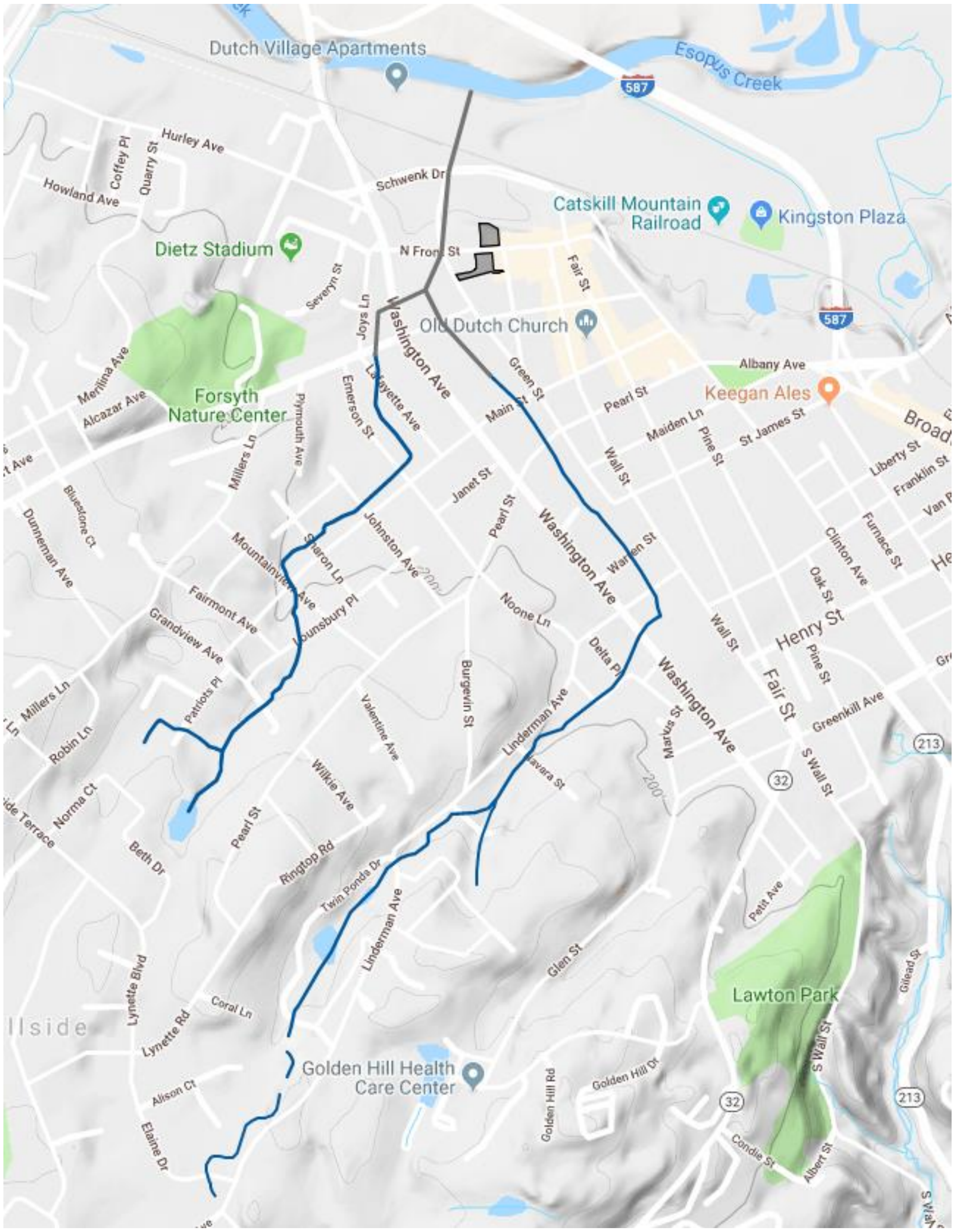

Figure 4.1: Map of Uptown Kingston, including the Uptown municipal parking lots (gray polygon) and the Tannery Brook. The Tannery Brook and Main Street Brook (blue lines) both flow north to the Lower Esopus Creek. The gray lines indicate the approximate location of the Tannery Brook in a section where it was buried, and not mapped. (Base map from Google maps, Tannery Brook and Main Street Brook delineations from Mickelson 2018.)

Figure 4.2: Photos of the Tannery Brook today. Behind Green Street (top left), at the Ulster County Family Court at Lucas Avenue (top right), and where it meets the Esopus Creek at the Dutch Village Apartments/Flood Control Structure #2 (bottom).

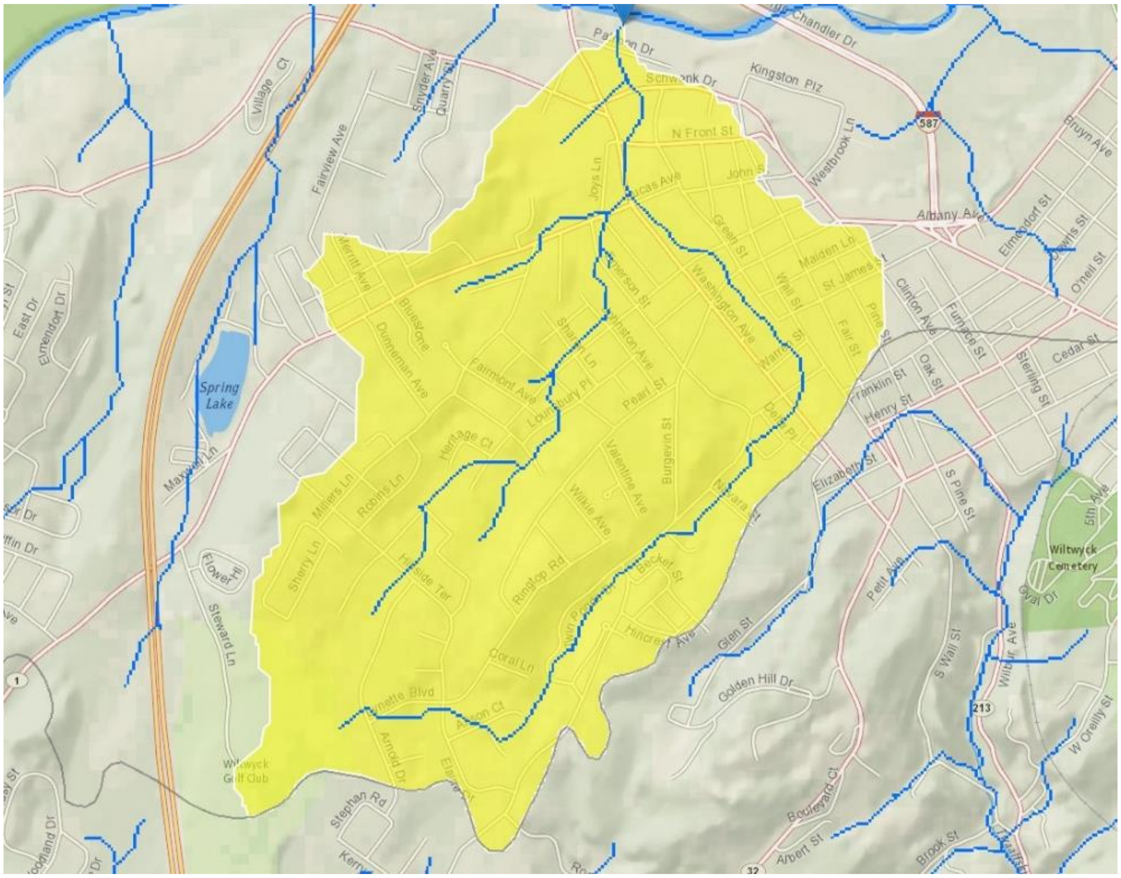

Figure 4.3: The Tannery Brook watershed, delineated based on topography (from U.S. Geological Survey 2018). The watershed area shown here is approximately 1.4 square miles; however, this map and calculation do not include storm sewers, which may drain different areas to the Tannery Brook. The headwaters of the Tannery Brook (to Washington Avenue) are also connected hydrologically to the Twaalfskill, which is not indicated here. While most of the watershed in within the City of Kingston, a small portion is in the Town of Ulster.

Agriculture (1652-1805)

Introduction

Dutch colonists from the Rensselaerwyk Patroon came to what is now Kingston in 1652, after acquiring land from the Esopus Native Americans (University of the State of New York 1918). Dutch settlement began in 1654, and the colonists began farming the fertile lowlands along the Esopus Creek. The Native Americans had already been farming beans, squash, and maize in these very productive floodplain fields, and it was estimated that they had been farming there for 500 years before the Dutch arrived (Evers 2005 pg. 21, Dietz 2013 pg. 71).

In 1658, conflicts with the Native Americans led the Dutch to build a dense settlement on a natural bluff enclosed by a wooden fence, or stockade (Figure 4.4). The stockade was 14 feet high, made with eight inch diameter trees, and measured 12,000 by 13,000 feet (O'Reilly Murphy 2013 pg. 7). Peter Stuyvesant, the director-general of the New Netherlands Colony, played a large role in Kingston's development in this location. Stuyvesant selected the area, ordered that it be enclosed by the stockade, and named it Wiltwyck in 1661 (Hickey 1952 pg. 35, pg. 58).

The location for the settlement was selected due to its natural protection, including steep slopes on the west, north, and east sides. The Tannery Brook was outside the stockade, to the west. The stockade was not only surrounded by steep slopes on three sides, but also could have been surrounded by water on those sides. Stuyvesant directed that a moat be constructed at the marshy foot of the slope to the north, between the village and the lowlands, to provide extra protection (Huey 1981 pg. 5, Evers 2005 pg. 47).

In 1888, Marius Schoonmaker wrote of the site:

> “The location appears to have been satisfactory to all, as the inhabitants proceeded at once to remove their dwellings and build the stockade. The selection was made on the 31st day of May [1658], and in three weeks’ time the palisade was substantially completed, the buildings removed, a bridge thrown across the brook beyond the gate near the northwest corner of the stockade, and a guard-house and temporary barracks built.
>
> “The location of the stockade was such that on the north, east, and west sides it ran along the brow of a steep declivity, with small streams of water, through wet marshy ground at the foot, and an extensive prairie flat beyond on the north and east sides; and on the west was a valley, with a brook running through the centre, bordered by considerable marshy ground. The last-named brook was very soon utilized for milling purposes; on the south there was a very extended sandy flat terminating in the narrow neck encompassed by the stockade” (Schoonmaker 1888 pg. 9).

The brook described to the west of the stockade, with considerable marshy ground, a bridge, and a mill, was the Tannery Brook.

Fear of conflict with the Native Americans resulted in a dense settlement within the confines of the stockade. In 1663, it was estimated that there were at least 34 houses within the stockade, and this grew to about 50 houses by 1676 (Schoonmaker 1888 pg. 41-42, Evers 2005 pg. 95). Although agricultural fields and a few buildings were outside of the stockade, expanding development across “the Kill” was not allowed due to the threat posed by Native Americans (Versteeg 1976 pg. 435).

The Dutch colonists and Native Americans fought two wars, and the Dutch expanded their settlement after each of these. After the First Esopus War (1659-1660), the stockade was moved west to include what is now Green Street, just before the valley of the Tannery Brook (University of the State of New York 1918). After the Second Esopus War (1663-1664), the Dutch took control of all of the lands occupied by the colonists with the Esopus territory, including the lowlands that they used for farming (Schoonmaker 1888, Evers 2005 pg. 76, pg. 78).

After colonization, agriculture in early Kingston was primarily based on grains. The Dutch also adapted the Native American tradition of growing maize, squash, and beans, along with tobacco (Evers 2005 pg. 129). When the stockade was first constructed, it was estimated that there were about 15 families cultivating 1,100 acres of land, and 20 families of laborers and mechanics (Hickey 1952 pg. 38).

The Mill on the Tannery Brook

The Tannery Brook was a significant feature for the new settlement, as the water provided power to grind grain at Kingston's first mill. In 1661, the colonists constructed a dam on the Tannery Brook at North Front Street to create a mill pond (Dietz 2012 pg. 141). This was the first documented feature to fragment the stream's course. The mill pond extended south from the dam to the west of Green Street (Figure 4.4, Schoonmaker 1888 pg. 29). This pond remained for about 150 years before it was drained in 1807 (Schoonmaker 1888).

Although there was a small tannery near the Tannery Brook in the 17th century, the Tannery Brook appears to have been called "Mill Creek" or the "Mill Kill" during the Dutch colonial era and possibly through the early 1800s (Sylverster 1880 pg. 194, Lionel de Lisser 1896). The Mill Gate was in the northwest corner of the stockade, and referred to the mill on the Tannery Brook. This was where most of the crops from the fields entered the stockade area (Versteeg 1976 pg. 246).

The earliest reference to the mill on the Tannery Brook was in 1661, when "Pieter Jacobsen requests the schout and Schepens to fix his charge for grinding corn" (Versteeg 1976 pg. 4). Grain that was ground at the mill was extremely important to feed the residents locally, but also to Kingston's economic development. Grain that had been ground was easier to ship and a more lucrative product than the raw product (Dietz 2012 pg. 7). Grain from Kingston was shipped via the Hudson River to other early colonies (Schoonmaker 1888). According to Nathaniel Bartlett Sylvester, "The mill stood about half-way between Frog Alley and the tannery, and was the means of supply for the whole country until… the dam was presented as a nuisance and drained…" (Sylvester 1880 pg. 173). In addition to the grist mill, there was also a saw mill at the Tannery Brook, which cut logs into boards for construction (Dietz 2012 pg. 7).

Although other mills were eventually constructed, the mill on the Tannery Brook was for some time the only mill in or around Kingston. This was partially due to geography; the Tannery Brook was located adjacent to the agricultural fields, and also had sufficient head to power the mill. Nathaniel Bartlett Sylvester wrote in 1880:

"The Hudson River on the east and the Rondout Creek on the southeast are prominent features in the topography of the city. The Esopus Creek in its northern course from the great southern bend in Marbletown flows near the city… A portion of the valuable "flats," or alluvial lands, are within the limits of the city corporation. Though thus surrounded by important rivers, the water-power for operating machinery is quite limited. Neither the Hudson nor the Rondout supplies motive-power… The Esopus has too little descent to be rendered available for mills in or near the city limits" (Sylvester 1880 pg. 167).

As the only mill in the vicinity of Kingston, the mill on the Tannery Brook was extremely important. Court records from 1668 indicate that if the mill burned down, grain would have to be taken to Albany for milling (Versteeg 1976 pg. 412). This threat was expressed by Tierck Claesen, after getting into an argument with Matthys Blangan over stolen liquor:

"'I have once assisted in putting out the fire in the guardhouse, which threatened to damage the mill. If it should happen again, I would not even move a hand in assisting to put it out,' and that the plaintiff and more others have been obliged to take ship to Fort Albany for the purpose of having their grain ground there, through the obstinacy of defendant Matthys Blangan" (Versteeg 1976 pg. 412).

Even after other mills were constructed, the mill on the Tannery Brook remained significant. An unknown author wrote in 1910 in the *Olde Ulster Historical and Genealogical Magazine*: "[By the early 1800s,] it was no longer the only mill… Still the old mill had retained its own, and many customers resorted here with their wheat and rye, their corn and their oats as their ancestors had done for generations" (Brink 1910).

The mill on the Tannery would have been approximately where Diesing's Bakery is today (111 North Front Street). The miller's house was across from the mill on Frog Alley. Although the mill was owned by Cornelius Barentsen Slecht, Pieter Jacobsen and Pieter Cornelius Louw were partners in operating the mill (Schoonmaker 1888 pg. 29, Huey 1981 pg. 5). Pieter Cornelius Louw is believed to have lived at the mill house (Huey 1981 pg. 5). The original section of the mill house was built between 1660 and 1665 (Huey 1981). The ruins of this structure (now called the Louw Bogardus house) are still visible at Frog Alley today; they are now a historic landmark and part of a park owned by Friends of Historic Kingston.

A question of paternity sheds light on the age of the mill and mill house. According to the records of an Ordinary Session, held October 17, 1662:

"Plaintiff [Grietjen Hendricks Westercamp] demands of defendant [Pieter Jacobsen] why he denies his child. Defendant answers, and says, 'I have my doubts about it.'

"Plaintiff says that defendant ruined her, and asks that he restore her to honor.

“Defendant denies that he ruined her, and says ‘she must prove this to me,’ and also denies that he promised to marry her. He asks her when she became pregnant, and when she was delivered.

“Plaintiff says that defendant made her pregnant eight days before Christmas, 1661, and that she delivered eight days before Kermis [the Fair], 1662. Plaintiff says she conceived at the mill-house of Pieter Jacobsen. Defendant requests two weeks’ time. The Schout and Commissaries grant the defendant two weeks time, and order plaintiff to prove at the next session that defendant ruined her” (Versteeg 1976 pg. 36-37).

Pieter Jacobsen’s mill house referenced here may have been the one on Frog Alley. As Grietjen Hendricks became pregnant at his mill house, it is possible that part of the Louw-Bogardus house was constructed as early as 1661.

The mill pond on the Tannery Brook lasted from 1661 until 1807, when it was drained due to public health concerns. Marius Schoonmaker wrote in 1888:

“In the early part of this century Kingston was visited with a great affliction in the prevalence of a malarial fever, frequently assuming a typhoid character. It was particularly prevalent in the western section of the village, in the vicinity of Green and North Front Streets. It prevailed for several years, increasing in virulence year by year, until the authorities were forced to take action in the matter. They became satisfied that the prevalence of the disease was attributable to the mill-pond attached to Benjamin Borgardus’s mill. The mill-pond covered the hollow west of Green Street from North Front Street on the north to a point below the present location of Lucas Avenue on the south. It was fed by two streams, the one coming in from the south and the other from the west.

“The village directors in 1806, a little more than a year after the organization of the village, under the powers conferred upon them in regard to the nuisances and their abatement, on the 8th day of November passed an ordinance declaring ‘that the Mill Pond lying in the west part of the village of Kingston, in the possession of Benjamin Bogardus, is a nuisance, and also the brook leading into the same through the lands of Jonathan Hasbrouck Lucas Elmendorf John C Masten and others, up to the South bounds of the tannery of Joshua Du Bois.’ And the directors further ordained ‘that the said Pond be drained within thirteen days.’ They also required the channel of the brook for the full extent to Du Bois’s tan-yard ‘to be cleaned out so as to allow free passage of the water; within the same time, under penalty of $25 for every forty-eight hours that it was neglected.’

“The directors encountering some difficulty in abating the nuisance without compensation, on the 19th of March, 1807, called a meeting of the taxable inhabitants, to take into consideration the question of compensating Mr. Bogardus for the loss of the pond. The meeting of the freeholders was held on the 21st of March, and it was unanimously decided that he should be paid $500, which sum Mr. Bogardus agree to accept as full compensation, and the money was subsequently raised and paid. Thus was a mill privilege swept away which had supported a mill for over one hundred years… The directors were correct in attributing the sickness to the effect of the mill-pond, as shown by the happy result, for with the removal of the pond as the cause, and the draining of its bed, the disease disappeared entirely" (Schoonmaker 1888).

The typhoid fever epidemic changed the shape of the Tannery Brook in a significant way, demonstrating the impact of public health decisions and water quality problems on this small stream. Joshua DuBois's tannery was located at Saint James Street and Green Street, and a "cleaning" of the Tannery Brook from North Front Street to Green Street would have been about a half mile of the stream's channel.

Brewing and Distilling

The Tannery Brook supported agriculture directly through irrigation, and indirectly by providing water power to process agricultural products. It also provided water to brew and distill beverages, including grain for beer or whiskey and fruit for brandy (Evers 2005 pg. 71).

Cornelius Barentsen Slecht, the original owner of the grist mill, was the village brewer by 1662; his brewery was adjacent to the Tannery Brook (Evers 2005 pg. 85). Two stills were built in 1662, and by 1664 there were multiple brewers and distillers (Versteeg 1976 pg. 13, pg. 161). Brewing and distilling were important industries for many years. Sylvester wrote that Slecht's brewery on the south side of the Mill Gate made good beer at that site for more than 150 years (Sylvester 1880 pg. 44). In 1820, an apple mill and distillery were located on the northeast corner of the intersection of North Front Street and Bridge Street (later called Washington Avenue, Schoonmker

1888 pg. 437). In 1887, a Sanborn Fire Insurance map included the C. Cummings Brewery at Lucas Avenue, at the site where the Tannery Brook joined the Main Street Brook (Sanborn Fire Insurance 1887).

Brewing excellent beer was a point of pride for Kingston. In 1679, members of the Labadist religious community came to Kingston from France to look for a site to establish their community, and they were impressed by the richness of the Esopus Creek's lowlands for producing crops (Evers 2005 pg. 94). They wrote in their journal that the beers from Kingston and Albany "were the heaviest beer we have tasted in all New Netherland and from wheat alone, because it (wheat) is so abundant" (Evers 2005 pg. 95).

Beverages that were brewed or distilled relied on local water sources, but boiling that water as a step in the process. This would have made them safer to drink than raw water, which might have had bacterial contamination. Beer, whiskey, and brandy were important beverages in colonial Kingston, in part for this reason (Dietz 2013 pg. 72).

Drinking Water

Early residents of Kingston relied on wells for drinking water and other household uses, along with water collected in cisterns. Andrew Hickey wrote in 1952:

"The first settlers at Esopus followed the plan of the Indians and obtained fresh water from the… the innumerable streams and springs that abounded near the lowlands and nearby mountains. Pollution of the water supply remained far in the future. The Dutch brought with them a liking for a well near their houses and constructed them with the large sweep to draw up water. The more prosperous and progressive built windmills to pump water and drive the mill for grinding corn. When the village was enclosed in 1658 the people obtained water from the stream near the northwest gate [the Tannery Brook]… Catch basins or cisterns were a part of nearly all early houses… Rain water was collected from the roof for all purposes. Large cisterns were located in strategic places in the village for fire protection and used until a piped water system was constructed. A few years ago two of these cisterns were uncovered during street repairs and made quite a stir in the newspapers" (Hickey 1952 pg. 101-102).

Today, cisterns are considered a green infrastructure practice because they store and reuse stormwater runoff from roofs (NYS DEC 2015). This stormwater management practice was in use in the 1600s, and may still be valuable today.

Livestock

In addition to growing crops in the fields, livestock were a significant part of early agriculture. Livestock also contributed to sanitation, public health, and water quality concerns. Manure was specifically a problem for the Tannery Brook. In 1669/70, "Pieter Cornelissen (Moolenaer – Miller) complains that many persons stop up his drain or water course by carting dung in the same. The hon. court will take measures concerning the same" (Versteeg 1976 pg. 438).

Cows and other livestock were kept within the stockade overnight, and every morning let out of the mill gate to pasture (Evers 2005 pg. 72). There were concerns about these animals obstructing the streets at night. In 1665, court records state:

"Whereas Schout and Scheepenen at Wildwyck have heard complaints that the round cannot, by night, freely and without obstructions pass along the streets, because the cattle are lying here and there in and about the streets, on account whereof not only by an unexpected alarm or other dangers, the guard and other burghers who might assemble, could not on account of said cattle occupying the streets, make a free use of the same, for fear of stumbling and falling over said cattle lying down during dark nights, but also that, on account of the obstruction, caused by said animals, they could not quickly and speedily come together at the spot where the danger would require them, therefore, Schout and schepenen of this village aforenamed have resolved and therefore order and command everyone to keep his cattle, at night, on his farm but not allow them to lie on and about the streets during the night, under penalty of a fine of one daelder every time for each head of cattle" (Versteeg 1976 pg. 250).

Keeping the streets clean was more of a concern because of fire hazard and public safety, but these issues also would have impacted water quality. Having dead and decomposing animals in the street was also an issue. A court order in 1665 required that dead animals be carried two rifle shots outside of the village and away from common roads (Versteeg 1976 pg. 254). The order stated that:

"…the residents of this village, prior to this, did not only leave the dead bodies of their large and small cattle in the streets of this village, but that some have even brought the said dead bodies close by the curtains outside of this community directly upon and near the common roads, which decomposing bodies, on account of their stench, not only much inconvenience passers by, but may also be the cause of bad diseases, owing to said nasty stench…" (Versteeg 1976 pg. 253).

Livestock roamed the streets of Kingston through the early 1800s. This was common practice in early American cities (McNeur 2014). In 1820, a new village charter included the office of street commissioner, and this role included enforcing ordinances on obstructions of sidewalks and roving swine (Blumin 1976 pg. 128).

The Threat of Fire

Properly disposing of garbage was important to the colonists. At the time, they were more concerned about reducing fire risk than protecting water quality. In 1664, residents were ordered to take their trash outside the stockade to the other side of the mill dam to burn:

"It was also proposed, and thereupon resolved, that, by public notice to the inhabitants here of the mischief and damage that may result from fire, the householders living near the Mill gate shall be forbidden to carry their straw and rubbish, for the purpose of being burnt, close to the village palisades, but shall rather take the same across the Mill dam. Whereupon the following placard was posted:

‘Whereas, experience teaches us the impropriety of throwing out straw and rubbish and of burning the same close by the palisades, wherefore great danger from fire may be expected, the Schout and Schepens therefore order that straw and rubbish shall be carted across the Mill dam by those living near the Mill gate, under the penalty heretofore fixed for that purpose. Further, all inhabitants here are directed to clear the streets, within four days, or straw and rubbish, so that, through the carrying of a light or the blowing out of a pipe of tobacco, a conflagration, such as the one at Amersfort on Long Island (God shield us), may not occur. And every one must attend every week to the said clearing and cleaning of the streets of the straw in front of his lot, under penalty of ten guilders’ fine. Let every one guard against damage’” (Versteeg 1976 pg. 168-169).

Having a water source to put out fires was critical in early Kingston. During the First Esopus War, Native Americans fired burning arrows over the stockade and started a fire in the settlement (Dietz 2013 pg. 46-47). The Tannery Brook was outside the stockade, and the colonists needed water sources inside to protect themselves. Based on this history and devastating fires in other colonial settlements, there was a general fear of fire (Versteeg 1976 pg. 169).

The water collected by cisterns was important for putting out fires, in addition to household use like cooking (Dietz 2013 pg. 126). This water filled buckets that were at the ready in case of emergency. Hickey explained:

“For years each householder was required to keep a water-filled 8-quart leather bucket containing his initials in his house near the front door. At fire call he hurried with his filled bucket and joined the volunteer bucket brigade… The year 1848 is the date the modern fire department was organized and hand engines purchased by the village” (Hickey 1952 pg. 102-103).

Cisterns and wells provided water for extinguishing fires from the 1600s through 1848, when the fire department was organized with a pump. There were several notable fires in Kingston during this time, including fires in 1776 and the burning of Kingston by the British in 1777. This kept a supply of water adjacent to buildings, and close at hand in case of a fire.

During the colonial era, “fire wells” were also dug to create a local water source from groundwater. Dietz wrote, “Where necessary, water sources were created by digging fire wells in the street (streets were not paved) at a convenient distance from the nearest buildings… Water in the fire wells often became rather obnoxious, but the water was good enough for extinguishing a fire” (Dietz 2013 pg. 128).

Brickyard

In 1665, Cornelius Hoogeboom requested a lot opposite of the mill dam for a brickyard (Versteeg 1976 pg. 198). Dietz estimated that Hoogeboom’s brickyard was adjacent to the Slecht brewery along the Tannery Brook (Dietz 2013 pg. 62). Although the first bricks for buildings in Kingston were imported from Fort Orange (Albany), bricks from the clay along the Tannery Brook were used throughout the village as it developed (Dietz 2013 pg. 7, pg. 43). The threat of fire from Native Americans reinforced the importance of using brick as a building material, rather than wood (Ditez 2013 pg. 62).

Roads and Transportation

There were no streets within the stockade area until 1664; Dover Street (later called Fair Street) was the only street in 1685 (Dietz 2013 pg. 19). Dover Street began as a narrow dirt road between today’s John Street and North Front Street, and it may have been used mainly for access to barns and other outbuildings ((Dietz 2013 pg. 19, pg. 88, Ford 2010 pg. 92). Main, North Front, East Front (later called Clinton), and Greet Streets developed, running parallel to the stockade fences (Ford 2010 pg. 162). This dense network of streets and buildings continues to be visible today, and Kingston's current-day "Stockade district" reflects the grid that was established in the 1600s.

Roof gables within the stockade faced the street, and directed roof runoff that was not collected by cisterns into the street (Hickey 1952 pg. 122). However, given the few streets and availability of green space, drainage was likely not a large issue within the stockade. According to the "1658 Plan of Stockade at Kingstowne," there were a number of gardens within the stockade (City of Kingston n.d.).

The bridge over the Tannery Brook at the dam was on the road to Hurley, an important transportation link in the early colony. North Front Street crosses the Tannery Brook at this location today. This would have been the only road to cross the Tannery Brook, as Pearl Street was not extended past Green Street until 1805 (Ford 2010 pg. 225). This road entered the stockade through the Mill Gate.

New roads fostered connections between other colonial settlements. By 1700, beavers and the fur trade had diminished in importance, and other natural resources had gained significance (Evers 2005 pg. 106). Agricultural products from Hurley and Marbletown (including wheat, oats, rye, and other grains), along with forest products (such as shingles and materials for barrels) and Shawangunk quartz conglomerate mill stones, were all brought to Kingston merchants by wagon (Evers 2005 106). Products that were not purchased locally were shipped down the Hudson River to New York

(Evers 2005 106). Kingston was an important connection between producers and consumers of goods, including connecting rural and urban areas.

Land Use

In the colonial era, land use was a very different concept than it is today. What we might consider residential and commercial uses were mixed within homes in the settlement within the stockade (Figure 4.6). Stores sold general merchandise without specializing, and most work done in or very near homes (Blumin 1976 pg. 14). Farmers typically grew their own food and made their own clothing and other goods (Blumin 1976 pg. 47). Outside the stockade was very light industry, agriculture, the commons, and wilderness.

In 1687, the British Governor Thomas Dongan granted a patent to the "Freeholders and inhabitants" of Kingston in trust to a Board of Trustees the land within the settlement, but also established the surrounding wilderness to the north and west as a Commons (Evers 2005 pg. 165). A "commons" meant that the land was open for all to use, and included the right to use woods, timber, feedings (gathered nuts and berries), pasture, swamps, and marshes (Evers 2005 pg. 165). This concept is very different from our land use framework today, in which all land is owned by some entity. In 1803, Kingston's trustees sold the last of its common land (Blumin 1976 pg. 21). All parcels were all owned individually, rather than collectively, after that time.

The colonists removed the stockade around 1700, as the populations of Native Americans had been decimated to the extent that they no longer posed a threat (Evers 2005). At this point, development could expand beyond the stockade area in earnest.

Schoonmaker wrote, “During the troublesome and dangerous times connected with the first settlements, it was the policy of the government to require settlers to locate as compactly as possible. But as dangers lessened, the village dwellings were abandoned by the farmers for the more convenient occupation of their farms” (Schoonmaker 1888 pg. 62).

Agriculture remained important in Kingston through the early 1800s, and farms and orchards to the west of the Tannery Brook persisted through the late 1800s (Sanford 1870). According to Stuart Blumin, Kingston was “a town of farmers” in 1820 (Blumin 1976 pg. 14). In addition to many residents continuing to farm, the primary businesses and industries within the town were designed to support agriculture (Blumin 1976 pg. 9). For example, manufacturing through the early 1800s met agricultural needs, including blacksmiths for plows, saddlers and harness makers, and a wagon-maker (Blumin 1976 pg. 15). However, agriculture diminished with the rise of industry in Kingston.

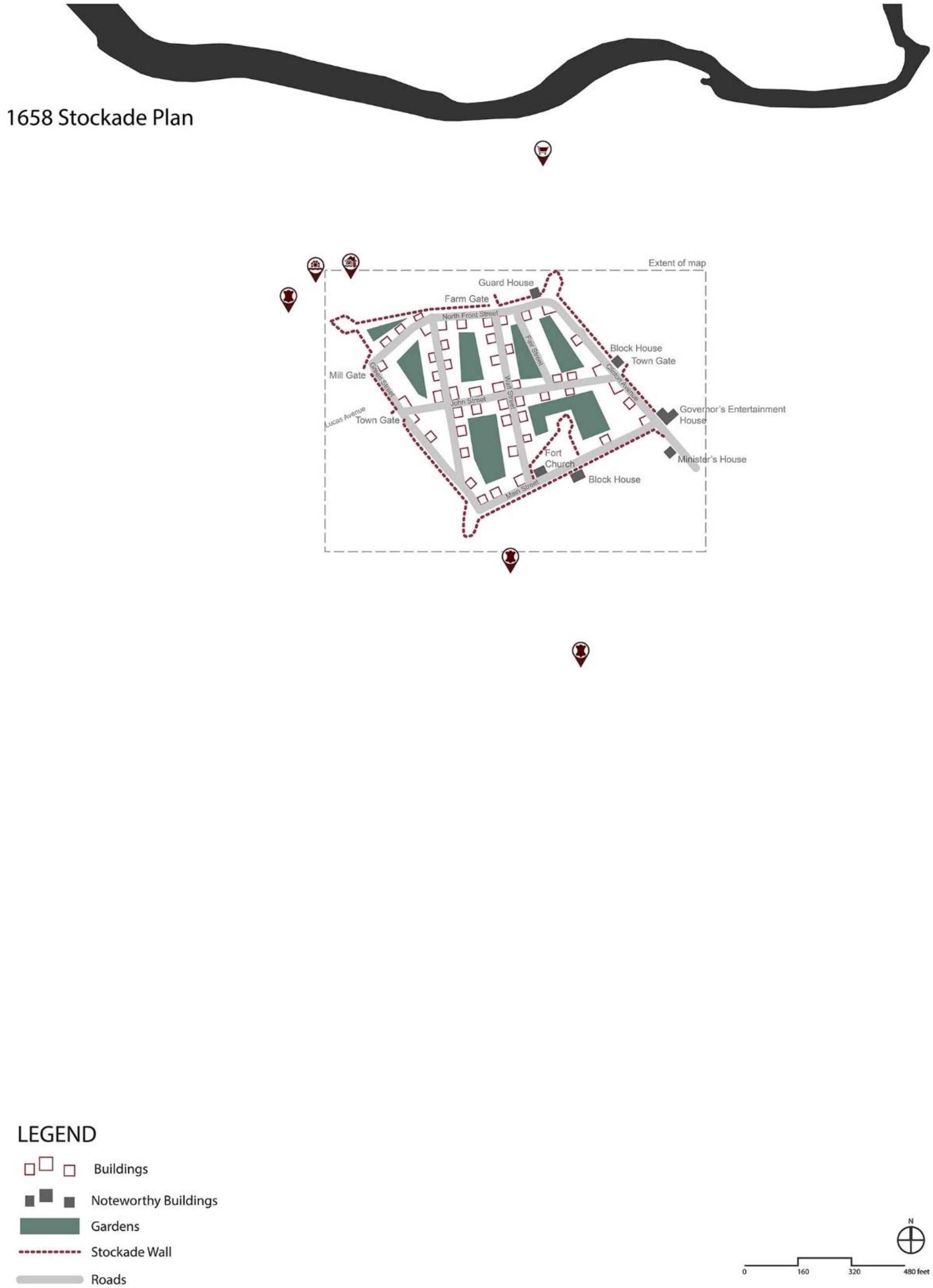

Figure 4.4: Digitized map of development inside Kingston’s stockade, circa 1658. (From “1658 Plan of Stockade at Kingstowne,” City of Kingston Engineering Archives.) Map by Jasmine Chen.

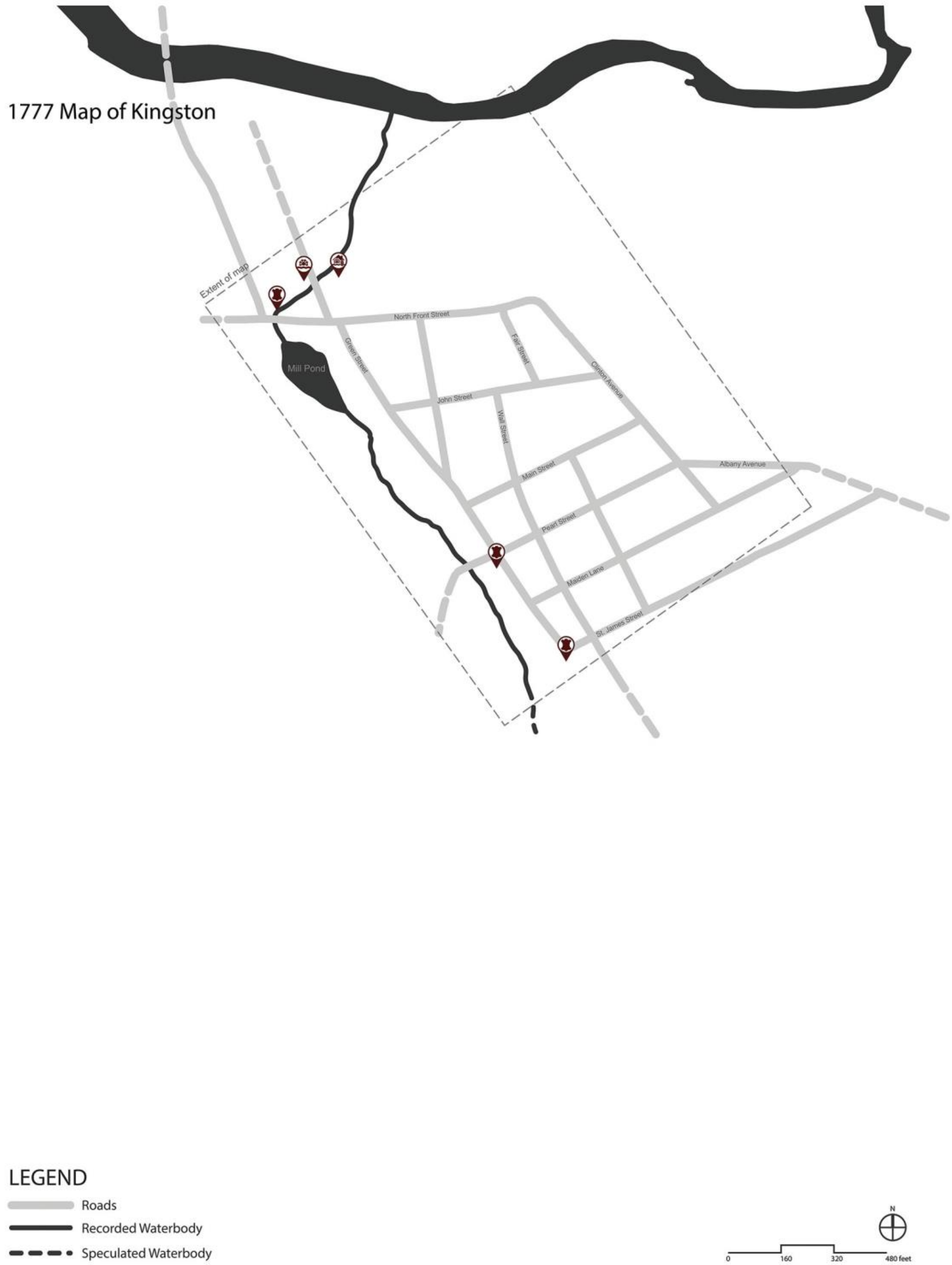

Figure 4.5: Digitized map of the Tannery Brook and mill pond, circa 1777 (from Schoonmaker 1888). Map by Jasmine Chen.

Figure 4.6: Digitized map of land use in Kingston in the early 1800s, including agriculture, commercial, and residential spaces. (From Blumin 1976 and Neil, E.O. 1846.). Map by Jasmin Chen.

Industry (1805-1872)

Introduction

In 1777, Kingston was New York State's first capital, and by 1805 Kingston was incorporated as a village. The period from 1805 to 1872 marked Kingston's transition from an agricultural village to an urbanized city. The City of Kingston was established in 1872 when the villages of Kingston and Rondout combined.

The Delaware & Hudson Canal opened on the Rondout Creek between 1826 and 1828, primarily to ship coal from Pennsylvania to New York City. The canal reinforced the importance of waterways to support industries. The Village of Rondout grew quickly, and the Village of Kingston also expanded as a result (DeWitt 1943 pg. 49). Although Kingston and Rondout were separate villages (Rondout was incorporated in 1849), their economics were linked. The D&H Canal was open to general merchandise, and this contributed to Kingston's growth into a small commercial city (Blumin 1976 pg. 52, pg. 58). The D&H Canal declined in traffic after 1872, was sold in 1898, and carried the last boat in 1909 (Blumin 1976 pg. 273).

Tanneries on the Tannery Brook

Several industries established themselves along the Tannery Brook, including three tanneries at North Front Street, Pearl Street, and St. James Street. A tannery is a place where hides are processed to become leather, and this requires water at various steps. Locating along a stream would provide a source for water, along with a place to dispose of wastes.

In 1834, all three tanneries were active (DuBois 1834). An advertisement in the Rondout Courier that year read:

"To Tanners. Valuable tanning establishment to let. The subscriber will let, and give immediate possession, the Tan Yard and privileges lately, and for a number of years occupied by Tobias Van Buren, in this village. There are three Tanneries on the stream; and this offered is one, and has the advantage of being the uppermost. The yard is also supplied with an excellent spring of water, and is in every respect convenient and well calculated for the business. Charles DuBois" (DuBois 1834).

The DuBois tannery at North Front Street was mentioned as early as 1806, when the mill pond was drained, and as late as 1834, when it was listed for rent (Schoonmaker 1888, DuBois 1834). This tannery was adjacent to the Tobias Van Buren house, which is still visible at 7 Green Street today.

The tannery at the corner of North Front Street and Washington Avenue was owned by Augustus Bruyn and called Kingston Tannery (Sylvester 1880 pg. 242). In 1846 it became Near & Teller Tannery, then Teller Brothers Tannery in 1871 (Sylvester 1880 pg. 242). The Teller Brothers Tannery appears on the 1887 Sanborn Fire Insurance map, with one building labeled "bark mill" and another labeled "bark shed" (Sanborn Fire Insurance 1887).

In 1950, Myron Teller remembered the tannery his father operated at North Front Street:

"This tannery was in operation as late as 1882, when he remembered playing around the vat room. There were some 15 to 20 tanks, five to six to eight feed and four by five feet deep. The tops level with the floor and a walk between them some 12 to 15 inches wide, all laid out like a checker board. These held various kinds of liquor to soak hides. Some were to soften for removing hair and flesh, others with tan bark liquor for curing and treating various grades of leather.

"The hides were tied together before placing in tanks so that when one was drawn out the next would be held at edge of tank ready for removal, when desired. These were then usually pulled up over a rack made like a ferris wheel and liquor would run off back into the tank. Wagon loads of bark were ground in a mill and then spread in large shallow round vat and piped across pivot at center. It would swing slowly and sprinkle water over the ground bark, something like todays percolated coffee pot. This would be allowed to soak in this fashion for days then drawn off for use in vats on lower floor.

"He also mentions the old Egbert Mullen Tobacco Works which was the adjoining building and is still standing. There the grinding mill was worked by a horse in the cellar, which walked around in circles to operate the mill to cut tobacco. All very exciting for youngsters" (Miller 1950).

A smaller tannery at the bottom of the hill on Pearl Street may have been active for a short time, appearing on an 1887 map of Kingston as it was in 1820 and referenced by Schoonmaker in 1888 as "an old tannery not in use" (Nichols 1887, Schoonmaker 1888 pg. 467).

The earliest mention of a tannery along the brook was in 1663, when a lot on the bank of "the Kill" for a tannery was granted to Jan Albersten van Steenwyck (Versteeg 1976 pg. 49). Another tannery was mentioned in 1694, "near Mill Creek, west of Kingstowne" (Sylvester 1880 pg. 194). These first tanneries were likely producing leather and other goods to be used locally.

Even in the 1800s, the tanneries in Kingston along the Tannery Brook were relatively small-scale, especially compared to the much larger tanneries in the Catskills that were active at the same time. In 1855, the census shows that Kingston's only tannery employed 5 men (Blumin 1976 pg. 65).

Other Industries

Other factories located near the Tannery Brook in the 1800s produced cigars, soap, candles, cabinets, chairs, upholstery, barrels, metal works, silver plating and saddling hardware, harnesses, carriages, stoves and tin products, and copper goods

(Sanford 1870, Blumin 1976). Like the tanneries, these other industries were relatively small (Blumin 1976 pg. 63). This was due in part to the lack of available head for water-powered mills. Saugerties developed a much larger manufacturing sector than Kingston, as they had much greater mill power with the Esopus Creek falls (Blumin 1976 pg. 57).

Limestone and bluestone were important extractive industries in and around Kingston. Limestone was used to make Rosendale cement starting in 1826 in Ulster County (Evers 2005 pg. 220). In 1837, the first bluestone quarry opened, and it expanded in the 1870s (Schoonmaker pg. 404, Evers 2005 pg. 229). Bluestone was transported through Kingston by wagon down North Front Street and Wall Street on the route to Wilbur or the Rondout waterfront (Evers 2005 pg. 230). These wagons were heavy and damaged road surfaces; they also caused dust in dry weather and mud in wet weather (Evers 2005 pg. 231). Hickey wrote, "As late as 1850 Wall Street, the principle business street, did not have sidewalks, and ruts in the street were so deep that on muddy days wagons frequently bogged down." (Hickey 1952 pg. 68). These roads had to be modified to handle the heavy traffic from bluestone quarries to the Rondout Creek (Hickey 1952 pg. 68).

In 1858, there was a complaint of industrial pollution in the Twaalfskill, a small stream that flows to the Rondout Creek (Blumin 1976 pg. 123). It is likely that water quality in the Tannery Brook was similarly impacted by the industries along it. Schoonmaker noted the impact that industry had on fish in the Twaalfskill:

"But the angler would likely continue his course farther down, and if unsuccessful in his search for trout continue onward until he reached the ponds of the Twaalfskill, where he was sure very soon to fill his basket with the small but delicious fish, called 'spaanacoker,' which when properly cooked furnished a treat not to be excelled.

Unfortunately, through the frequent drainage of the ponds and the erection and working of a tannery above, that delicate fish has become extinct, and its delicacy and toothsomeness are now only to be remembered and talked of, not enjoyed. The young boys of that day, the writer can allege from experience, enjoyed many a delightful Sunday morning breakfast when discussing the results of their angling in those ponds the previous afternoon. The fish were then abundant, and it was no uncommon thing, when the line was provided with two or three hooks, to find, draw after draw, every hook laden with its captive" (Schoonmaker 1888 pg. 426).

Roads and Transportation

New roads were built beyond the original stockade area, and several crossed over the Tannery Brook. Pearl Street was extended west past Green Street in 1805, and this section was originally called Big Vly Lane after the Tannery Brook's marshy valley (Ford 2010 pg. 225). The words "vly" and "fly" were derived from the Dutch word "vlai," which meant a valley or wetland along a stream (Versteeg 1976 pg. 760, Ford 2010 pg. 225). Lucas Turnpike (later Avenue) was laid out in 1807 (Ford 2010 pg. 185). Bridges and culverts to cross the Tannery Brook would have continued to fragment its course, confining the stream within its channel at those locations (Figure 4.7, Dietz et al. 2016).

Within the stockade area, Wall Street was extended to North Front Street in 1827 (Ford 2010 pg. 304). According to DeWitt, this area contained a meadow until the road was extended (DeWitt 1943 pg. 23). Despite the relative density, there was still green space within the stockade area in the early 1800s.

Poor drainage in streets caused public health concerns, linking water management and transportation infrastructure. Standing water was a significant sanitation and drainage issue. In 1854, there was a complaint of "odors and stenches" in Rondout's streets (Blumin 1976 pg. 122). In 1860, a Village of Rondout election was won on the issue of local improvement projects, including street-draining and grading (Blumin 1976 pg. 136). Hickey wrote, “The result of these dread diseases induced the village [of Rondout] fathers to pave the streets, build sidewalks and divert a stream of water that ran down the hill through Colder Street, later Division Street, now called Spring Street; and to forbid cows and pigs wander about the roads endangering the water supply” (Hickey 1952 pg. 189-190).

The need for improved management of streets was not exclusive to Rondout. Roads were unpaved in Kingston until the 1850s, when new bylaws and village charters expanded the role of local government and they graded streets and built curbs, gutters, crosswalks, and sidewalks (Blumin 1976 pg. 118). Village of Kingston government minutes from 1860-1861 also include laying out new streets, curbing, and guttering old streets (Blumin 1976 pg. 131). These drainage decisions represent early forms of municipal stormwater management.

As both Kingston and Rondout grew, public transit helped residents travel from one village to another. Before 1851, residents of Kingston and Rondout walked, rode horses, or drove carriages (Moffett 1997 pg. 7). The first urban transit system was an omnibus, started in 1851; this was a wagon pulled by one or two horses, enclosed on three sides with a roof (Moffett 1997 pg. 9). A horse railroad was built in 1866 by the Kingston and Rondout Railroad Company to run from Rondout to Kingston, with a terminus at North Front Street and Green Street (Moffett 1997 pg. 13). A depot for the horse railroad was built on the corner of Washington Avenue and North Front Street in 1873 (Moffett 1997 pg. 17).

Having animals run certain regular routes through the villages concentrated their waste in specific locations. Horse droppings at stopping points accumulated and caused complaints of odors; rather than remove the waste, the railroad company sprinkled it with lime to manage the smell (Moffett 1997 pg. 14-15). These horses also needed water, and watering troughs were set up in convenient places using water from cisterns (Hickey 1952 pg. 70). Water was also used to keep down dust on the roads they traveled (Hickey 1952 pg. 70).

Salting for winter transportation was done as early as 1875, when “much salt” was applied to the horse railroad tracks on Division Street (now Broadway) to reduce ice (Moffett 1997 pg. 20). In the 1880s a “salt car” was added to the horse railroad in the winter to help maintain the tracks (Moffett 1997 pg. 28). In January 1905, a sand wagon was used to help trolleys get up hills on Hasbrouck Avenue and Broadway (Moffett 1997 pg. 73). Today, salt and sand are regularly applied to roads in winter weather, and are known to impact water quality.

Around 1893, the horse car was replaced by an electric trolley (Moffett 1997 pg. 7). Buses replaced the electric trolleys in 1930, and were operated by Kingston City Transportation (Moffett 1997 pg. 96).

Railroad tracks were built across the Tannery Brook in the lowlands near the Esopus Creek. In 1868, the Rondout and Oswego railroad was constructed from Kingston Point to the Catskills, and it crossed the lowlands (Kingston Land Trust 2018). At this site, the Tannery Brook was confined within a culvert to allow for the railroad to be developed. This area included a lumberyard, which is still in the same location today, along with other industrial facilities (Sanford 1870, DeWitt 1943 pg.

25). Rail was a key transportation method to ship goods, eventually outliving the D&H canal.

Land Use

A commercial center developed along North Front and Wall Streets, industries located on the outskirts of the dense village core, and residential development extended outward. Green space within the business district was taken up by new buildings, and agricultural fields were subdivided into many small lots with individual houses. The development of new roads and buildings in areas that had previously been open space would have shifted the water budget of a small stream like the Tannery Brook.

The first *Kingston and Rondout Directory* was created in 1857 to catalogue streets, businesses, and residents (Blumin 1976 pg. 117-118). Due to the growth of both Kingston and Rondout, there was a new need for wayfinding maps to get around and find specific locations. The 1858 business directories indicated a clear specialization of land use into commercial, industrial, and residential areas (Blumin 1976).

By the 1850s, small industrial districts had been established north and south of the main commercial core in the Village of Kingston (Blumin 1976). These were centered on North Front Street and Saint James Street, adjacent to the Tannery Brook.

At the same time, upper Wall Street and North Front Street became a clearly defined commercial district (Blumin 1976 pg. 105). These streets became filled with unseparated commercial buildings (Blumin 197 pg. 120). Homes in this area had been surrounded by lawns, trees, and barnyards, but these were increasingly developed (Blumin 1976 pg. 120). As the central business district grew, people began to move outside the crowded commercial area, and suburban areas developed (Blumin 1976 pg. 111-112).

Local economies drove significant changes in housing patterns. In 1820, most workers were a part of their employers' household (Blumin 1976 pg. 85). Slaves, journeymen, and apprentices would all live together in the same building as merchants or other employers and their families (Evers 2005 pg. 114, 115). Slavery had been significant in Ulster County; about 10% of Kingston's population in 1820 were black slaves and 2% were freedmen (Blumin 1976 pg. 35). Slavery was abolished in New York State in 1827, as the economy shifted from agriculture to industry.

Large agricultural parcels began to be subdivided, and rented units became more common (Blumin 1976 pg. 95). Kingston's population grew from just under 3,000 in 1820 to 16,640 in 1860, and all of these new residents needed a place to live (Blumin 1976 pg. 75). The housing stock needed for workers shifted to smaller houses and apartments, rather than large homes that included these workers. By 1860, most workers had their own household and were employees of large companies (Blumin 1976 pg. 85-86). Merchants and other businessmen still had large, fashionable houses (Evers 2005 pg. 197).

Small settlements also established themselves on the outskirts of town at this time. According to Alf Evers, "Misfits of mixed ancestry lived as outcasts" on the edges of the village of Kingston in makeshift structures (Evers 2005 pg. 115). Mutton

Hollow, near the current Route 28 traffic circle, was an African American settlement in an area that was prone to flooding (Evers 2005 pg. 390).

In contrast to the increasingly industrial landscape, scenery and the beauty of the natural world became an important idea. In the 1840s, Andrew Jackson Downing (from Newburgh, NY) shaped perspectives on landscape in the Hudson Valley and beyond, including concepts like the beautiful, sublime, and picturesque. In the late 1800s, when Rondout was rapidly developing with industry, Uptown Kingston maintained a more pastoral appearance, and “scenery was coming into fashion” (Evers 2005 pg. 231). At the same time, there was an interest in improving homes and gardens (Evers 2005 pg. 248). The view of Kingston from Golden Hill (headwaters of the Twaalfskill) was painted and celebrated (Evers 2005 pg. 231). The 1896 book *Picturesque Ulster* included many photographs of Kingston’s streets and buildings, and included photographs of the Tannery Brook and Carter’s Pond (Lionel de Lisser 1896).

Figure 4.7: Digitized map of 1870 Beers map of Kingston, Rondout, and Wilbur (Sanford 1870). Map by Jasmine Chen.

Infrastructure (1872-1946)

Introduction

In 1872, the villages of Kingston and Rondout combined to form the City of Kingston. Although the two villages had very different characteristics, their local economies supported each other (Blumin 1976 pg. 105). While improving drainage had long been a role of local government, the new city was able to hire municipal staff and had more capacity to take on large-scale engineering projects. New forms of water infrastructure were emerging to support the "sanitary city" (Melosi 2008). Kingston's Board of Health was established in 1872 as part of the city's charter (University of the State of New York 1918). The office of the City Engineer was established in 1896, and the Board of Public Works was created in 1915 (University of the State of New York 1918). The Plumbing Board was also created in 1892 (University of the State of New York 1918).

Drinking Water

Drinking water infrastructure carried water from the Saw Kill in Woodstock into people's homes in Kingston starting in 1883, and the system transitioned from private to public by 1896 (Figure 4.8). Prior to this, residents relied on well water, and since the colonial era many buildings had cisterns to collect roof runoff for household use. As early as 1860, certain houses had indoor plumbing with water from cisterns that was pumped up to the roof (LaValle, personal communication, August 4, 2017).

Kingston established a Board of Water Commissioners in 1880 as a municipal department, and this department took over water supply in 1896 (University of the State of New York 1918). William DeWitt wrote in 1943: (1943 pg. 258):

> "Thought was given to a supply of pure water… Uptown Kingston was already envisioning that through private enterprise. An out of town promoter was busy with that – Samuel P. Low, a large, heavy man who we can just recall. He secured the backing of public-spirited citizens, also others both public-spirited and wise in risking a dollar. Here was an opportunity – in the '70's and '80's the custom was to leave the water supply for public corporations. Mr. Low had looked ahead for years and had his plans already. He chose the Sawkill stream of Catskill Mountain water, with its principle source beyond the village of Woodstock at the head-waters of the Mink Hollow. The water had been tested, the lands bordering found purchasable, with water rights, all the way down to Kingston, with location for a dam for Reservoir No. 1. Everything was in order and necessary private capital was attracted…
>
> "Mr. Low and his backers had completed one reservoir and a pipe line to the City by 1883 and charged the inhabitants as reasonable rates as possible but more than Cities that owned their own water works. So, in 1896 the City purchased from the private water company all their water rights and property… We proceeded to build additional reservoirs, a filter house to make the water even more perfect as to odor, taste, color, etc., such as absence of bacteria, in fact, the best in the State or Nation. This determination to improve in these ways resulted in two more dams being constructed, and then the acquisition of the large Cooper's Lake …"

In the late 1800s, water infrastructure was seen as a symbol of accomplishment and beauty in cities (Soll 2013 pg. 29). In New York City, the High Bridge and Croton Reservoir (in Manhattan, later replaced by the New York Public Library) were visible examples of public drinking water infrastructure at work (Soll 2013 pg. 29). The 1896 book *Picturesque Ulster* devoted several pages to large photos of Kingston's drinking water infrastructure, including the dam, reservoir, and filtration treatment facility, in addition to other scenes from Ulster County (Lionel de Lisser 1896). This reinforced this idea of infrastructure as beautiful and celebrated.

The improvement in water infrastructure and water pressure was significant for fighting fires. DeWitt described a fire that broke out near the corner of Fair Street and

North Front Street: “That might have become one of our largest fires, approaching those of 1776 and 1894, of the same section to the west, but our water pressure from our comparatively new Mountain water supply was so great that our volunteer firemen saved the town” (DeWitt 1943 pg. 23).

By piping water into Kingston from Woodstock, rather than drawing water from groundwater wells or cisterns, the water budget would have been significantly for the Tannery Brook. These pipes brought in large volumes of water from outside the watershed, and increased the amount of water easily available for household use. The existing methods of treatment weren’t sufficient for the much larger volumes of wastewater produced, and sewer infrastructure soon followed in Uptown Kingston.

Wastewater

In 1889, the first sanitary sewer system was installed in Uptown Kingston (Figure 4.9). These sewer pipes collected wastewater across the ward, brought it to a central trunk line along the Tannery Brook, and discharged it directly into the Esopus Creek. Based on articles in the *Kingston Daily Freeman*, there were numerous discussions on the issue of sewage, from public health concerns to who was going to pay for or benefit from the system (Kingston Daily Freeman 1889a).

The earlier forms of wastewater management, such as cess pools were not sufficient, and the Tannery Brook was suffering from pollution. In January 1889, the *Kingston Daily Freeman* reported:

> “…Referring to the danger from cholera and other diseases, he [Dr. R. Loughran, Health Officer] said there are from 40 to 50 water closets on the tannery brook, from Linderman-avenue to its outlet. Washington-avenue is being built up, and must be relieved from this stench. He also said there are 15 to 20 water closets from

Henry-street to Pettit's, on the Twaalfskill. Families are enemies because of the contamination of the brook. The only relief Kingston has now is by cess-pools. But property is too valuable in portions of the First Ward to be taken up by cess-pools. He urged at length favorable action by the Common Council.

"William M. Hayes said it seemed to him every man of ordinary intelligence could see the necessity of a system of sewerage. Sewerage becomes more necessary because of the water and there must be some relief… The want of sewerage is injuring business interests. Men have said they would build if there were sewers, but without sewers they would not do it. Manufacturing interests suffer without sewers" (Kingston Daily Freeman 1889a).

Not only were the odors a problem, but installing sewers was an important step to promoting economic development, including businesses and manufacturing. Space for on-site systems was also increasingly limited as density increased.

Sending sewage from Uptown Kingston to the Rondout Creek at Wilbur was considered, but installing the sewers along the Tannery Brook to the Esopus Creek was much less expensive. In March 1889, the *Kingston Daily Freeman* Reported:

"The question of building sewers was discussed at length. The advisability of running the main to Wilbur instead of in the Esopus Creek was talked over. The greater expense of running a main to Wilbur, especially for sewers in the First Ward, because of the great depth to which sewers must then be laid, whereas the natural grade for the main along the tannery brook would require so little excavation that it would be comparatively cheap, was referred to. In regard to the objection made by Saugerties people to sewering in the Esopus Creek, it was claimed that the system of sewers in contemplation, because of the great volume of water which would pass through the pipes, would so dilute the sewage that it could not be detected in the Creek a short distance from the outlet, and that in any case the swift-running waters of the Esopus, especially in passing over the rifts and falls, would completely purify the water even though the amount of sewage was much greater than would ever be emptied in from Kingston" (Kingston Daily Freeman 1889b).

At the time, it was believed that rivers were able to naturally treat waste, and no additional treatment was necessary. The Esopus Creek appeared to have sufficient flows to dilute the raw sewage and reduce any risks to the Village of Saugerties downstream. Today, we recognize that “swift-running waters” do not completely purify waters of sewage pollution.

Sewers were built throughout the neighborhood between 1889 and 1896 (City of Kingston 1897). Sanitary sewers replaced the cess pools, water closets, and other rudimentary on-site systems. In 1914, the *Kingston Daily Freeman* described a sanitary ordinance that required all property owners to connect with the sewer system and abandon outside vaults; that year, the newspaper also reported on the “stench” of the “that famous Tannery brook which has been the subject of considerable discussion at board of health meetings from time immemorial” (Kingston Daily Freeman 1914).

The wastewater pipe discharging into the Esopus Creek was only in use for about 20 years. In 1909, New York City’s Board of Water Supply constructed a large sewer interceptor in a tunnel 80 feet below Washington Avenue (Figure 4.10). This was the location that was considered in 1889 when the first sewers were constructed in Uptown Kingston, but was determined too expensive due to the deep excavation required. The tunnel redirected sanitary sewage from Uptown Kingston away from the Esopus Creek and into the Twaalfskill Creek and Rondout Creek. The new Ashokan Reservoir was being constructed on the Esopus Creek in the Catskills to provide drinking water for New York City. This was anticipated to reduce flows downstream into the Esopus Creek such that it would no longer be able to dilute the raw sewage (City of Kingston 2016).

The tunnel was constructed below Washington Avenue through approximately 6,200 feet of earth and rock (Board of Water Supply of the City of New York 1909 pg. 55). It extended from “the point where the Tannery Brook Sewer crosses North Front street, along North Front street and Washington avenue, crossing under the Wallkill Valley R. R. to South Wall street, and along a right-of-way through private property to the first manhole on Wilbur avenue north of the culver where the Twaalfskill crosses said avenue" (Board of Water Supply of the City of New York 1909 pg. 48). The tunnel connected to sanitary sewers that were already in place along Wilbur Avenue near Gilead Street (Board of Water Supply of the City of New York 1909).

The tunnel crossed under the Tannery Brook in two locations, at North Front Street and near Linderman Avenue. The Tannery Brook was already enclosed in a culvert at both of these road crossings (Board of Water Supply of the City of New York 1909).

Although most of the tunnel was constructed in bedrock, a portion was also built through about 200 feet of soil (Board of Water Supply of the City of New York 1909 pg. 56). In those sections, the walls and roof of the tunnel needed to be reinforced: "…the side walls shall be of concrete and shall conform to the dimensions as given. The cover for the tunnel lining shall be an 8-inch brick arch of the best Hudson River brick laid in Portland cement mortar… All the space outside of the tunnel lining shall be refilled with earth or rock and thoroughly compacted" (Board of Water Supply of the City of New York 1909 pg. 55, pg. 57).

Over time, vertical shafts were installed to connect previously serviced areas to the sanitary sewer system, or to reduce surcharging in areas that had existing sewers (City of Kingston 2016). Later, portions of the sanitary sewer were capped and an upper chamber was constructed within the tunnel to carry separated stormwater (City of Kingston 2016). When stormwater was added to the tunnel, it discharged directly into the Twaalfskill at Gilead Street, off of Wilbur Avenue.

The City of Kingston eventually built a wastewater treatment plant on the Rondout Creek in 1946. Funding to build the treatment facility came from the New Deal's Clean Air and Water Act, a federal grant program (Evers 2005 pg. 409).

Water and sewer infrastructure continue to impact urban streams, through interbasin transfers and complex vertical/groundwater dynamics. Pressurized water pipes are prone to leaks, while gravity-fed sanitary sewers are not typically well-sealed (Kaushal & Belt 2012). These exchanges of water between are difficult to observe, but likely play a role in the Tannery Brook's water quantity and quality today.

Recreation

Despite the reliance on the Tannery Brook to convey waste, it still played important role for recreation. William C. DeWitt wrote in 1943, "The Tannery brook was large 60 years ago… We used to try to catch brown trout when the stream rose. Maybe they were only small pike or inferior fish" (DeWitt 1943 pg. 13).

In the late 1800s, a shallow pond was created on the Tannery Brook between Main Street and Lucas Avenue, where Ulster County Family Court is located today. Through the early 1900s, Carter's Pond was known as an excellent location for ice-skating in the winter. Although it was not at the same location as the original Mill Pond, and much smaller, it was an area that would had previously been impounded. According to DeWitt:

"A Mr. Corey came here and invested extensively in real estate… Mr. Corey purchased land on Green Street. Built new houses and attempted to fill a pond in rear and build it into a small rowing and skating lake. This was formerly Carter's Pond, taking in Tannery Brook, which we have spoken of heretofore. It can be seen now (1942), south of Lucas Avenue, next to the George B. Styles resident and grounds, now the home of Harry Styles, son, and his wife and children, and there can be noted the extensive stone wall built by Mr. Corey to make the pond water tight. This failed, as the pond would not fill up, but Mr. Corey's other investments were successful" (DeWitt 1943 pg. 100-101).

Although Carter's Pond was too shallow for boating, it was deep enough to ice skate. By the 1940s, this area was no longer a pond, but described as a swamp where children still played (Feldman, personal communication, January 23, 2017). Carter's Pond was private property, rather than a public park. Even today, most of the access to the Tannery Brook is on private property, as the stream flows through backyards. The stream today is most visible at road crossings, and has very limited public access.

The steep valley of the Tannery Brook also created an ideal site for winter sledding, especially at Pearl Street (Schoonmaker 1888 pg. 447-448).

"Rural" roads along the Tannery Brook near Linderman Avenue were popular destinations for walking in the early 1800s. Schoonmaker wrote:

"At the time of which we are now writing [1820] there were many pleasant and inviting walks in the immediate neighborhood of the village of Kingston… Afternoon and evening strolls were very fashionable with the young gentlemen and ladies, and much more enjoyed than the confined air of the parlors. If those old lanes and byways, now by the march of improvement either obliterated or shorn of their attractiveness and beauty, could talk, and relate things of the past, it is believed that many soft words and plighted vows exchanged between those who have since passed through the stem realities of life would be the burden of their tales.

"The first of these favorite walks turned from the village at the junction of Pearl and Green streets, and then, after crossing the brook and following a farmers' lane for a short distance, a bed of flat rocks was reached, several acres in extent, presenting a smooth, even surface, broken only by narrow fissures separating the different layers…

"The place is now entirely changed; our great canal, commingling the waters of the Erie and Hudson, and other large works of improvement, have drawn upon its resources until its surface is entirely changed, so that it now forms the blooming garden of a gentleman of leisure. Passing across the rocks over to the "big fly road" [now Pearl Street], a short walk brought the pedestrians to the top of the high ground in the rear of the village, where one of the most lovely landscapes opened to the view, embracing the village of Kingston, surrounded by its broad expanse of lowlands and cultivated farms, and the lordly Catskills bounding the horizon in the distance, thus presenting a broad, extensive view with which the eye could never tire" (Schoonmaker 1888 pg. 424).

The "march of improvement" and "large works of improvement" changed the nature of these roads, as Kingston grew as a city. This walk crossed the Tannery Brook at Pearl Street, and led to the stream's headwaters. Another popular walking destination described by Schoonmaker was Love Lane, which was just south of the Tannery Brook (Schoonmaker pg. 425). Love Lane was later renamed Marius Street, after Marius Schoonmaker (Ford 2010 pg. 194).

Roads and Transportation

Earlier maps showed a tributary to the Tannery Brook that traveled along Lucas Avenue. This stream is particularly evident in the 1870 Beers map of Kingston, Rondout, and Wilbur (Figure 4.7, Sanford 1870). The Main Street Brook used to join this tributary at Lucas Avenue, before this tributary joined the Tannery Brook to the east of Washington Avenue. The tributary along Lucas Avenue disappears around the late 1800s, and was likely incorporated into storm sewer infrastructure. After this time, the Main Street Brook is delineated more clearly on maps (Figure 4.11).

Main Street was extended past Green Street to Washington Avenue in 1887, then to Johnston Avenue in 1896 and Grand View Avenue in 1918 (Ford 2010 pg. 189). The Main Street Brook may have been excluded from maps previously because this area had not been developed, and was not well known. Today, the Main Street

Brook is the only surface-level tributary to the Tannery Brook, and joins the Tannery Brook underground north of Lucas Avenue and to the east of Washington Avenue.

In 1892, wagons and the trolley were the primary modes of transportation in Kingston. In 1900, the first car was driven in Kingston, and by the 1920s it had replaced horses and wagons (O'Reilly Murphy 2013 pg. 23). This shift to the automobile drastically changed transportation; this is discussed further in the next section.

Land Use

In 1880, Kingston was considered "quite a rural city, compactly built at only a few points" (Sylvester 1880 pg. 210). However, residential development continued to expand outside the original stockade area and up the hills west of Washington Avenue. These changes in land use continued to impact water quantity and quality in the Tannery Brook. In 1880, Sylvester also commented that, "The early Bogardus mill of Kingston village was upon a stream that is now scarcely more than a ditch or sewer in that part of the city" (1880 pg. 167). New residences used more potable water and produced more wastewater within the watershed. Development also increased stormwater volumes, adding new roads, houses, and other impervious surfaces. Storm sewers discharged directly into the Tannery Brook at each of its major road crossings (Figure 4.12).

Proper waste management was a concern, particularly as the Tannery Brook flowed through backyards. In 1928, the *Kinston Daily Freeman* reported:

"Dr. [E.H.] Loughran called attention to the Tannery Brook and said that many people were accustomed to throw the sweepings from the lawns and other refuse into the brook, trusting to Providence that it would be floated away from their own property, but in many instances it simply floated as far as the next neighbor's property where it dammed up the brook. Sanitary Inspector Cook, who had investigated several complaints, said that he had found the bodies of dead animals floating in the brook.

"It is likely that the board will notify all property owners along the brook to cease throwing refuse into the stream. It is also probable that the brook will be cleaned in the near future by the board of public works as a sanitary measure" (Kingston Daily Freeman 1928).

The Tannery Brook Shaft

Over time, separated storm sewers were added to an upper chamber within the tunnel under Washington Avenue, which was originally constructed by New York City to intercept sanitary sewage (City of Kingston 2016). These new storm sewers carried runoff away from the Tannery Brook's watershed and discharged it into the Twaalfskill at Gilead Street.

In 1993, a section of the Tannery Brook itself was redirected into the Washington Avenue tunnel and into the Twaalfskill. The reach that flows along Linderman Avenue from Twin Ponds to Washington Avenue was disconnected from its historic stream channel to alleviate flooding downstream. The City of Kingston built a 30 inch diameter shaft to carry the stream 80 feet down into the storm sewer within the tunnel (City of Kingston 2012). Water could bypass the shaft and overflow into the original Tannery Brook stream channel during floods (Milone & MacBroom 2015).

In addition to the Tannery Brook Shaft, two other stormwater shafts enter the Washington Avenue tunnel. These are at Elizabeth Street (24 inches in diameter) and Greenkill Avenue (36 inches in diameter); all three shafts were installed to reduce flooding, property damage, and public safety (City of Kingston 2012). Both of these shafts are down-gradient from the Tannery Brook, within the Twaalfskill watershed. When the tunnel was constructed in 1909, the Twaalfskill's headwaters (also called the Jacob's Valley Brook) crossed under Washington Avenue in a culvert (Sanford 1870, Board of Water Supply of the City of New York 1909). The Greenkill shaft was located at this site, and appears to be conveying the Twaalfskill's headwaters more directly downstream, bypassing a section of the stream that used to flow along North Wilbur Avenue and Pine Street (Sanford 1870).

During the investigations to construct the Tannery Brook shaft, about three feet of sediment was found deposited in the bottom of the tunnel (Clough, Harbour & Associates 1992). This was likely sediment from groundwater that entered the tunnel as the original brick arch deteriorated (2013 contract with GEA). They also found a two-foot deep void space in the soil column when digging a shaft pilot hole, located beneath limestone bedrock and above soft silt and clay soil (Clough, Harbour & Associates 1992).

Washington Avenue Sinkhole

Severe storms in spring 2011 caused a sinkhole to open on Washington Avenue near Linderman Avenue, where the Tannery Brook shaft enters the Washington Avenue tunnel (City of Kingston 2016). Another sinkhole formed in the same location in March 2012, approximately 2-3 feet in diameter and 7 feet deep (City of Kingston 2012). Washington Avenue collapsed in April 2012.

A significant amount of groundwater and sediment had leaked into the Washington Avenue tunnel at the Tannery Brook shaft, due to deterioration of the

100-year-old brick arch tunnel (City of Kingston 2012, Swenson 2013). Underlying construction, as well as the Tannery Brook Shaft, appeared to contribute to the infrastructure's failure (Gallo 2015). The sediment that entered the sanitary sewer also caused operational problems at the wastewater treatment plant (City of Kingston 2012).

While most of the tunnel was built through rock, there were a few sections where it was constructed through soil. These areas had to be reinforced by concrete and a brick arch (Board of Water Supply of the City of New York 1909). The section between Linderman Avenue and Marius Street was constructed on sandy soil well above the bedrock (Gallo 2015). The soils settled and moved over time, and groundwater carried soil into the tunnel. Because of settlement issues over the years, Kingston's Department of Public Works had had to repair the road surface at this site "from time to time" (City of Kingston 2012).

These soil sections had long posed difficulties for infrastructure. In January 1911, contractors working on the Washington Avenue sewer line struck a mud seam between Linderman Avenue and Marius Street; the Colonial City electric trolleys that ran on Washington Avenue were stopped because they were concerned that settling might cause the cars to derail (Moffett 1997 page 78).

In 1948, City of Kingston Engineer A. F. Hallinan inspected the tunnel with a construction worker, who recalled early issues with subsidence. "We then proceeded to Washington Avenue and Main Street where Mr. Cragan described the cave in, or subsidence, due to the tunnel passing from a rock section to a clay section and thru which the tunnel was laid in a shield under pressure. He claimed that in this area there was 200 to 300 feet of muck thru which the tunnel passed before coming to a rock section" (Hallinan 1948).

Initial sinkhole repairs included stabilizing the soil around the Tannery Brook shaft and restoring the surfaces that had been damaged by collapse on both public and private properties (City of Kingston 2013). The repairs also included installing stormwater piping to convey the Tannery Brook from Hewitt Place to the Tannery Brook shaft (City of Kingston 2013).

In addition to the sinkholes on Washington Avenue in 2011 and 2012, other infrastructure failures associated with the tunnel included groundwater leaks and structural damage to the manhole and tunnel at Lucas Avenue (City of Kingston 2016). The manhole and tunnel at Lucas Avenue is near where the Main Street Brook is buried under Washington Avenue. There was also a major sewer collapse off Gilead Street in 2013 (City of Kingston 2016).

Although Washington Avenue was reopened to traffic in May 2016 and repairs were completed in June 2016, problems remained (City of Kingston 2016, Kirby 2016 May 23). In November 2015, there was another major sewage spill into the Twaalfskill (Kirby 2015). By January 2016, it became clear that the grouting used to stabilize the soil around the Tannery Brook shaft blocked the wastewater pipe within the Washington Avenue tunnel, contributing to the overflow (Kirby 2016a). During the grouting process, the lining of the sanitary sewer was damaged and collapsed, allowing the grouting material into the pipe (Kirby 2016b). The Washington Avenue tunnel was estimated to convey about 1 million gallons of sewage per day, about a quarter of Kingston's total sewage (Kirby 2016a).

As the grouting was removed and the sanitary sewer was repaired, the Tannery Brook shaft was not used, and the Tannery Brook flowed in its historic stream channel toward the Esopus Creek. The grout was removed in April 2018, and the tunnel was relined in June 2018 (Zangla 2018). After this time, the Tannery Brook was placed back into the shaft, flowing into the Twaalfskill and the Rondout Creek.

Washington Avenue was fully or partially closed to traffic for about 7 years, and as of 2018, the total cost of sinkhole repair was well over $10 million (Zangla 2018). Former City of Kingston Mayor Shayne Gallo, who held office from 2011 to 2015, was quoted by the *Kingston Daily Freeman* in 2014: “Every time I drive around the streets and see a barrel or a cone or a depression in the road, I get concerned. It’s sinkhole paranoia, infrastructure paranoia” (Kirby 2014d). This was a major disruption, and while residents near the sinkhole were the most affected, residents throughout Kingston and the region were highly aware of the sinkhole and its impact. *Kingston Daily Freeman* described a toilet placed on the curb adjacent to the Washington Avenue sinkhole as possibly “a form of guerrilla street commentary by long-suffering residents” (Kingston Daily Freeman 2017).

Figure 4.8: Digitized map of drinking water infrastructure in Kingston in 1883 (from Kingston Waterworks 1883). Map by Jasmine Chen.

Figure 4.9: Digitized map of the first sewer infrastructure in Uptown Kingston in 1889 (from City of Kingston 1889). Map by Jasmine Chen.

Figure 4.10: Digitized map of the sewer interceptor and tunnel constructed under Washington Avenue. (From Board of Water Supply of the City of New York 1909.) Map by Jasmine Chen.

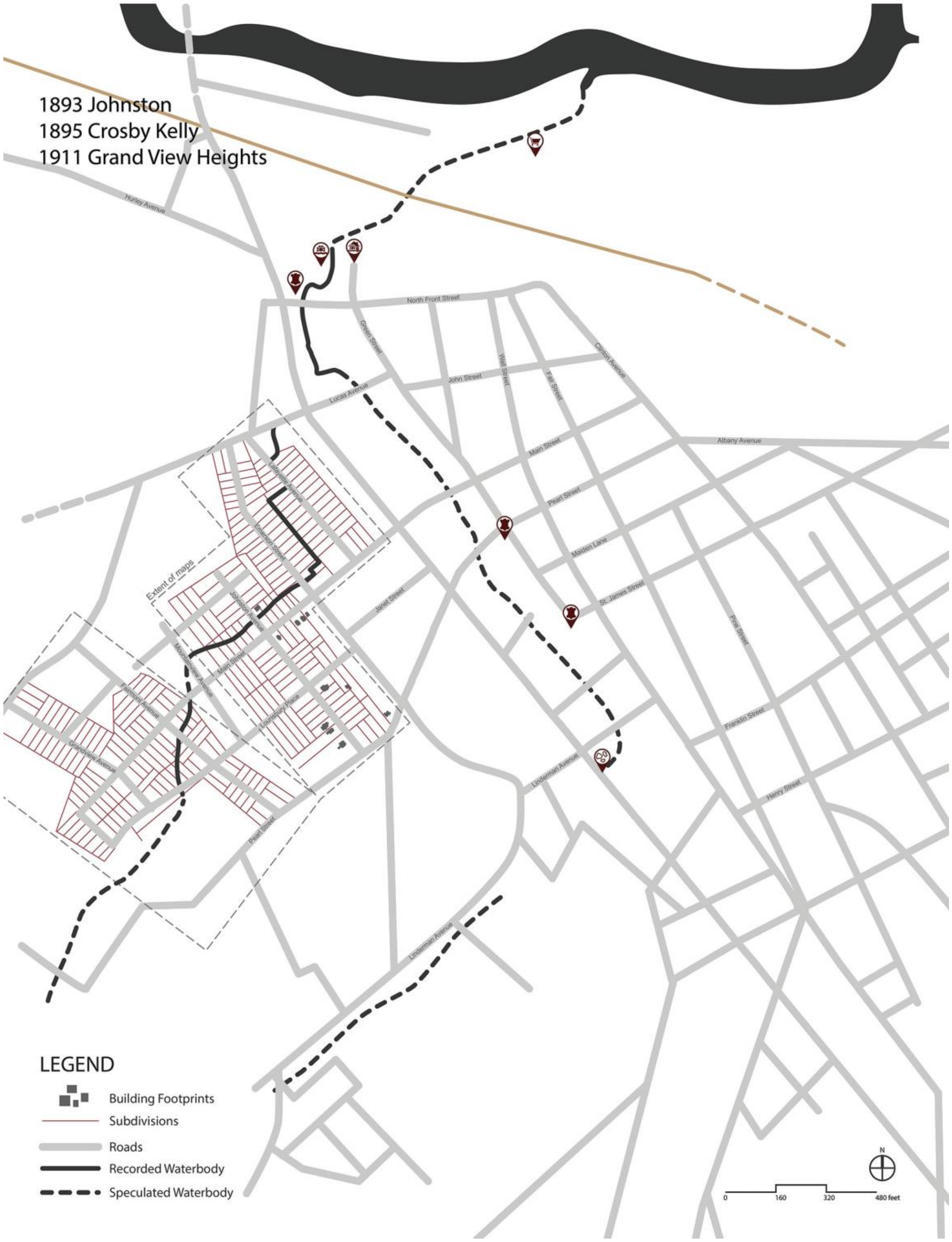

Figure 4.11: Digitized map of subdivisions in the Main Street Brook watershed. (From "Colonial Park - Map of the Subdivision of the Estate of Daniel Johnston," 1893, Ulster County Archives; "Map Showing Property Owned by Crosby Kelly," 1895, Ulster County Archives; "Map of Grand View Heights," 1911, Ulster County Archives.) Map by Jasmine Chen.

Figure 4.12: Digitized map of sanitary and storm sewers in Uptown Kingston. (From City of Kingston 1916a and City of Kingston 1916b.) Map by Jasmine Chen.

Flooding and Burial (1946-1999)

Introduction

The 1950s brought IBM and suburban development in and around Kingston, and the 1960s brought urban renewal. The character of Kingston's business district changed, with increased chain stores and a reliance on cars. Many historic buildings were demolished to create parking lots to support these businesses.

By 1947, the Tannery Brook was confined to walls in many sections, and increasingly disconnected from its natural floodplain (City of Kingston 1947). The channelization of the stream within walls or culverts disconnected it from its floodplain, and exacerbated flooding problems elsewhere. Several sections of the Tannery Brook were buried over time to reduce flooding, reduce erosion, and make room for new suburban-style development.

Flooding

The Esopus Creek's extensive floodplains were long used for farming, and the Tannery Brook originally crossed the lowlands before it entered the Esopus Creek. The lowlands were within the floodplains of the Esopus Creek, and very prone to flooding; flooding has long been an issue for the Tannery Brook, as well. As early as 1663, a flood of the lowlands from the Esopus Creek resulted in a major loss of crops (Hickey 1952 pg. 57).

While there have been many recorded floods, a few stand out. A major flood in 1760 damaged and broke the mill dam on the Tannery Brook at North Front Street. Marius Schoonmaker quoted a letter written by Charles DeWitt on August 11, 1760:

“But of all the showers of rain that ever I saw, I have seen none to equal that on Saturday the 26th [1760]… Mr John Du Bois fulling mill broke all to pieces. Mr Petrus Smedes mill, in Kingston, the dam broke and gutter gone, £100 will not make that. The whole loss here is very considerable, besides a very melancholy sight to see people's whole dependence of subsistence thrown to pieces” (Schoonmaker 1888 pg. 200-201).

In the 1880s, another spring flood caused major damage along the Tannery Brook. William DeWitt wrote:

“Older folks, now, 1942, may recall a freshet in the Spring of the 1880’s, when that part of the Tannery brook passing along the Donovan property rushed so fast down upon the Williams saw-mill property as to put the mill temporarily out of business and flood the lands paralleling Washington Ave. and Green St., all the way over the Chipp property now facing Warren St., and piling the waters high over the banks as it ran under or over Pearl St., bac of Charles DuBois’ yard there, then but a few feet above the normal banks of the stream… thence the flood over-ran Main St. and continued in the back years of other stone houses, and frame ones, too, filling all spaces, and carrying away all movable articles into the pond area on Lucas Ave., where Mr. Cory years later tried building a large skating and pleasure pond; then so on, joining the main Tannery stream and flooding North Front St. to the low lands bordering the Esopus Creek from the Catskills” (DeWitt 1943 pg. 13-14).

During another spring flood in 1900, waters of the Tannery Brook were estimated to be 10 feet deep at Lucas Avenue.

“The Rondout Creek, Hudson River, Esopus Creek and Wallkill creeks are all over their banks, and considerable damage has been done. In this city many cellars are flooded. The Tannery Brook, that flows through a valley back of Green-st., is swollen to the size of a large creek, and at Lucas-ave. the water is fully ten feet deep. The lowlands are covered with water from Esopus Creek, and they look like a river over half a mile wide. The Catskills were covered with snow, which the rain melted, and before the morning Esopus Creek will rise higher than ever before in its history” (New York Daily Tribune 1900).

The lowlands along the Esopus Creek were increasingly developed after railroad tracks were laid. Although today we recognize the value that floodplains and wetlands have in storing water, wetlands were historically not appreciated. An article from 1889 on the Tannery Brook and the marshy lowlands below North Front Street states that, “It was generally admitted that the marsh was a disgrace to the city and should be drained” and “…where the ditch ran through tillable land it should be covered, or it would be a damage to the land” (Kingston Daily Freeman 1889c).

Kingston Plaza, a suburban strip mall, was built in the lowlands in the 1960s. After the Esopus Creek’s worst recorded flood in March 1951, the U.S. Army Corps of Engineers began to plan a large-scale flood control project to protect the plaza. The Flood Protection Works for the Esopus Creek in Kingston, New York were originally authorized by Congress in the Flood Control Act of 1948, section 205, and endorsed by the NYS DEC in 1971 (NYS DEC n.d.).

Many originally thought that the Ashokan Reservoir would eliminate Esopus Creek flooding in Kingston, but that was not the case. The Ashokan Reservoir was not designed as a flood control project; nevertheless, it was estimated to have reduced peak discharge during that 1951 flood at Kingston by 40 percent (U.S. Army Corps of Engineers 1962).

Planning for the Esopus Creek flood control project was conducted through the 1960s. In 1971, a detailed project report recommended flood walls. Construction on the project began in 1977 and was completed in 1978 (NYS DEC n.d). A 1969 drainage map of the Kingston Plaza site shows the previous course of the Tannery Brook traveling northeast across the lowlands; this is labeled “existing stream” (Brinnier & Larios 1969). Buildings were constructed on top of the previous course, and the Tannery Brook was buried and moved to the west side of the site to enter the Esopus Creek more directly. The Tannery Brook now enters the Esopus Creek through a flap gate at Drainage Structure No. 2. This flood control project disconnected the

Tannery Brook from the Esopus, and also disconnected the Esopus Creek from its extensive floodplain.

Today, the Esopus Creek flood control project consists of about 1,570 feet of levees, 938 feet of concrete flood walls, retaining walls and numerous interior drainage facilities including gated gravity conduits, continuous swales and ditches, drop inlets, catch basins, control manholes, a ponding area, and a small pumping station (NYS DEC n.d.). The City of Kingston owns and maintains the flood control project (NYS DEC n.d.). The flap gate on Flood Control Structure #2 is designed to close if floodwaters from the Esopus Creek rise to a certain level. This would close off the Tannery Brook. When this would occur, instead of flowing into the Esopus Creek, the Tannery Brook's water would be pumped to a holding pond in the northeast corner of Kingston Plaza. After the floodwaters fall, the pond would be pumped into the Esopus Creek (U.S. Army Corps of Engineers 1978).

The absence of the Tannery Brook in the flood control planning and management documents is notable. The Tannery Brook is not mentioned at all by name in the US Army Corps of Engineers survey of the Kingston project, although the pipe where it met the Esopus Creek was shown (U.S. Army Corps of Engineers 1962). This document also included calculations for "interior drainage," which did not appear to include the Tannery Brook's watershed (U.S. Army Corps of Engineers 1962 pg. 84). Tannery Brook also not mentioned by name in the flood control operations and maintenance manual (U.S. Army Corps of Engineers 1978).

Although Kingston Plaza was an important economic investment to protect, not everyone agreed that a large-scale flood control project was the best direction.

Public comments for the project from 1956 indicated that George Mollenhaur, Master of the Kingston Grange, suggested a “small watershed program of small retention dams… Large dams cause needless destruction of valuable farm land and villages. Flood control program should be coordinated with upland soil and water conservation measures which would be applied to small watersheds” (U.S. Army Corps of Engineers 1962 pg. 125).

Burying the Brook

Upstream, additional sections of the Tannery Brook were buried in pieces to make room for new development and to reduce flooding in certain areas. Although there were proposals in the 1940s to completely bury both the Tannery Brook and the Main Street Brook, these plans were never constructed (Figure 4.13). A detailed 1947 stream survey shows walls along many sections of the Tannery Brook, and it had been largely straightened and channelized by this time (City of Kingston 1947).

Instead, the brook was buried in portions, on individual parcels. While this continued the Tannery Brook’s fragmentation, it cleared space for new suburban-style development. Many of the buildings between Lucas Avenue and Schwenk Drive were constructed in the 1960s and 1970s, where the Tannery Brook used to run. The Stadium Diner (127 North Front Street) was one building constructed in 1962 where the Tannery Brook was buried. The Stadium Diner is still at this location today.

“The diner is to be installed and operated by a corporation, the Stadium Diner Inc. and will be known as The Stadium Diner. The Reis property is also the site of the Rondout-Woodstock Oil Co. Inc. On the land years ago was the Mullen tobacco plant, which had been a landmark in the area for generations in the vicinity of the intersection of North Front Street and Washington Avenue. A large area of the present property had been eroded through the years by the flow of the Tannery Brook and it was filled in several years ago" (Daily Freeman 1962).

The Tannery Brook was buried at several other locations. By 1975, Marc Fried described the Tannery Brook as "… the tiny stream that now flows largely through underground culverts along the gully between Green Street and Washington Avenue…" (Fried 1975 pg. 30).

Although burying streams would seem to reduce flooding taking water away from the surface, it can actually exacerbate issues. Culverts can be undersized, and may not be able to convey flood waters. Increasing development upstream also changes stream flows, and culverts that may have been appropriately sized at one time could be undersized in the future.

In July 2014, Esposito's Dry Cleaners and tuxedo shop at 25 Frog Alley was badly flooded after a storm. The cause of the flooding was actually a 500-pound heating tank from another site that somehow got lodged within the storm sewer (Kirby 2014b). However, the size of the storm sewers at this site also contributed to the problem. The storm sewers were under the building and the parking lot, and they transitioned from a diameter of 50 inches to a diameter of 16 inches (Kirby 2014b). The building was originally constructed in the early 1970s, and at one point was an A&W restaurant (Kirby 2014b). According to the Kingston Daily Freeman, "Swenson said the pipes on the property were installed about 50 years ago and have become insufficient to handle stormwater flow, given development in the area since then." (Kirby 2014a).

City of Kingston installed a new, 25-inch diameter stormwater pipe that went around the building, rather than under it, in summer 2014 (Kirby 2014c, Kirby 2014e).

Although it was a “freak” accident, where a tank the same size as the storm sewer happened to block the pipe, this location was the Tannery Brook’s historic stream channel. The Tannery Brook had been buried and moved slightly east to travel along Frog Alley; however, excess water has a way of finding paths of least resistance.

Land Use and Transportation

In 1956, the IBM Kingston plant was dedicated and the New York State Thruway opened. Commercial activity shifted away from the historic business at Wall Street and North Front Street to new shopping centers on Albany Avenue and Route 9W in the Town of Ulster with chain stores (Evers 2005 pg. 398). Kingston Plaza was constructed in the Esopus Creek lowlands in part to help bring retail back within the City of Kingston (Evers 205 pg. 404).

In addition to suburban development, urban renewal played a significant role in shaping Uptown Kingston. The need for parking in Uptown Kingston resulted in the demolition of many historic buildings. One of these was the DeWaal Tavern, which had been renowned for its dance floor since before 1804. Schoonmaker described the house in 1888:

“The house was burned down in the great fire of 1804, during the occupancy of Mr. Dewaal, and immediately afterward rebuilt as it now appears. During Mr. Dewaal’s occupancy it was kept as a public house, and the old house, as well as the new one, contained the favorite dancing hall. The new one was particularly celebrated on account of its beautiful spring floor” (Schoonmaker 1888 Pg. 438-439)

The DeWall Tavern was demolished in 1963 to create the North Front Street municipal parking lots. Not everyone was enthusiastic about the demolition of this historic structure to make room for parking. Sophie Miller wrote in her “Do You Remember” column in 1962:

> “Several readers have spoken to me about The DeWaal Tavern which is going to be taken down, and the land black-topped for uptown parking… Perhaps somehow, by someone, this historical structure, which is said to have had a spring floor can be saved, or preserved and the parking can be done around it. It would make an interesting local museum, or even some sort of recreation or rest place, or information building. I know it has been altered but it was one of the buildings from our Kingston’s early history and I am sure is fascinating to strangers, just as it is. Remember the fascination of countries in Europe are their famous historic structures, for which Americans spend fabulous sums to see and brag that they saw them. Let us hold on to the little we have in our young country” (Miller 1962).

A turning point for historic preservation in Kingston occurred in 1969-1970, when the beautiful Central Post Office on Broadway was demolished and replaced by fast food buildings. In 1970, the Senate House was listed on the National Register of Historic Places, and the rest of the Stockade District was added five years later. In 1975, Friends of Historic Kingston purchased the Louw-Bogardus house, and Converse Street was re-named Frog Alley.

As part of the Pike Plan, Wall Street and North Front Street business owners commissioned Woodstock artist and designer John Pike to design canopies to provide shelter for shoppers; however, these were not well-built and developed leaks (Evers 205 pg. 404). Drainage is still a problem at these canopies today, which could be an opportunity for green infrastructure practices in the future.

Figure 4.13: Digitized map of 1946 plans to bury the Tannery Brook and Main Street Brook. (From New York State Post War Public Works Planning Commission 1946a and New York State Post War Public Works Planning Commission 1946b.) Map by Jasmine Chen.

Toward a Sustainable City? (1999-2018)

Today, the last glimpse of the Tannery Brook before it disappears underground is through the storm drains at the Ulster County Family Court parking lot on Lucas Avenue. Public access is limited, as the Tannery Brook travels mostly through private property and is most visible from road crossings.

During construction for the sinkhole on Washington Avenue, the Tannery Brook was placed back into its historic stream channel, rather than being diverted into the Twaalfskill. The Tannery Brook shaft was repaired in summer 2018, and the section of brook from Twin Ponds to Washington Avenue was returned into the storm sewer within the tunnel once again. There were also plans in the works to bury an additional section of it near Linderman Avenue (Koester, personal communication, April 25, 2018).

The Twaalfskill has also suffered from flooding, and in 2018 the City of Kingston undertook a flooding study that included this section of the Tannery Brook, given its hydrologic connection. The connection was also included in the Tidal Rondout Creek Watershed Management Plan, and improving this section of the Tannery Brook was one of the top three priority projects (Milone & MacBroom 2015). Due to flooding in the Twaalfskill, the plan also recommended that the City of Kingston consider restoring the Tannery Brook to its historic course (Milone & MacBroom 2015).

Since 2000, new federal and state regulations have changed how communities manage stormwater. This included the Municipal Separate Storm Sewer System (MS4) program, and the NYS Stormwater Management Design Manual. In 2016, green infrastructure practices were constructed at the municipal parking lots on North Front Street. Runoff in these parking lots no longer flows into storm sewers, directly into the Tannery Brook. Instead, it soaks into the soil through rain gardens, dry wells, and pervious pavement. These practices filter and infiltrate stormwater, which helps reduce runoff and improve water quality. There are also new perspectives on the role of rivers in cities, as many cities are restoring buried streams through daylighting.

According to Pickett et al. (2013), "Sustainable places are those that succeed in supporting resilient ecological, social, and economic processes. Sustainability is a normative social goal, resulting from a civic dialog, and suggesting processes of change toward that goal." Attributes of a sustainable city include adding ecosystem services to engineered features, integrate planning and management across municipal departments, flexible and decentralized governance (including community, neighborhood, and private organizations), public-private partnerships, and more bottom-up decision-making and holistic approaches (Pickett et al. 2013). The social and economic implications of urban rivers, along with ecological goals for sustainability, are important considerations for future planning (Dufour & Piegay 2009).

We deal with the impacts of past decisions, but a better understanding of the Tannery Brook's history can inform decision-making today. The City of Kingston has actively worked to reduce sewer overflows, improve watershed planning, survey natural resources, and adapt to climate change. The Tannery Brook and Main Street Brook were mapped by Hudsonia as part of a habitat study, and were included within Kingston's Natural Resources Inventory (Hudsonia 2014, Mickelson 2018). The

Tannery Brook was recognized as a water resource, not just a ditches or sewer, with the potential to benefit Kingston. It will take more work to move toward a sustainable city; however, small cities may be particularly well-suited to incorporate sustainability into practice (Pickettt et al. 2013). We should examine our current values to find a place for the Tannery Brook to be meaningful to Kingston today.

4.4 DISCUSSION

After green infrastructure practices were constructed in the Uptown municipal parking lots, stormwater from this area infiltrated into groundwater. Topographically, the parking lots are within the Tannery Brook's watershed; however, the stream is enclosed in a pipe through this reach. Groundwater would not be able to influence the stream, and it's likely that the groundwater eventually flows to the Esopus Creek.

Although the original inquiry began with asking where water from the Uptown municipal parking lots went, the history of the Tannery Brook became a central part of this research. This history illustrated how changes in the local economy, land use, and governance shaped the Tannery Brook, and how changing values impacted decision-making on behalf of this small urban stream.

The Tannery Brook supported Kingston's economic development throughout its long history, from powering mills, to supporting industries, to removing waste, to being buried to make room for suburban development. These ecosystem services have been significant. The Tannery Brook has also caused economic damage from flooding and infrastructure failures, like the sinkhole on Washington Avenue.

The form of the Tannery Brook changed with its function, including being dammed for a mill pond or skating pond. Walls were built to contain the Tannery Brook and reduce damage from flooding, followed by burial and being enclosed within pipes.

The Tannery Brook has been fragmented by various features, starting with the dam at North Front Street in 1661. Roads crossing the stream enclosed portions of it in bridges or culverts. The Tannery Brook was disconnected from its floodplain through walls and encroaching development. The Esopus Creek flood control project disconnected the Tannery Brook from the Esopus Creek, which would have impacted fish populations, flooding, and other dynamics. As it was buried in pieces, fragmentation continued to the extent where the Tannery Brook was largely not recognized as a stream. The inter-basin transfer of the headwaters of the brook from the Esopus to the Rondout via the Twaalfskill reduced its flows downstream.

The area now known as the “Stockade District” has long been a dense urban core, first as the principle settlement for Dutch colonists and later as the central business district for Kingston. Outside of that area, land use changed from agriculture to industry to residential development. These changes in the Tannery Brook’s watershed, along with the changes in the local economy, would have impacted both quantity and quality of water in the brook.

Several issues reappear again and again over the Tannery Brook’s history. These include trash and waste disposal, flooding, public health, and sanitation. Although these issues may stay the same, there have been different tools to address them, and different perspectives and values that inform decision-making to manage them.

Because of the high level of hydrologic connectivity through the stormwater system, and the disconnection of urban streams from riparian zones and floodplains, the greater watershed area becomes much more important than the traditional riparian area (Kaushal & Belt 2012). There are opportunities to restore the functions of riparian areas, such as processing or transforming nutrients, throughout the watershed, through green infrastructure practices and other approaches (Kaushal & Belt 2012).

Green infrastructure is one valuable watershed-based tool that could improve conditions in the Tannery Brook. Implementing green infrastructure throughout the Tannery Brook's watershed could help mitigate flooding and improve water quality. Physical conditions in the Stockade area seem well-suited to infiltration practices (sandy soils, high depth to groundwater). Social conditions may also be suitable, as people have an interest in neighborhood attractiveness for businesses and quality of life.

Vietz et al. (2016) identified stormwater harvesting through cisterns and rain barrels as a particularly important method to re-balance urban water budgets. Given the long history of cisterns in the Tannery Brook's watershed, this may be a useful strategy to consider in Kingston. Green infrastructure implemented throughout this neighborhood could make a significant difference in volume control for the Tannery Brook's watershed. It is also common for roof runoff to enter the sanitary sewer system in Uptown Kingston, so focusing on disconnecting rooftop runoff from the sewer could also relieve pressure on the wastewater treatment plant (LaValle, personal communication, March 14, 2018).

There might be different opportunities for green infrastructure in the headwaters of the Tannery Brook and Main Street Brook, especially due to more clay-y soils. Both of these streams have ponds in their headwaters, and actions could be taken to make these more functional. For example, the ponds could be altered to be more like wetlands, and play a more intentional role in retaining runoff, reducing sediment, or transforming nutrients. Green infrastructure practices in these areas may be able to store and more slowly release runoff downstream, even if it doesn't all infiltrate into groundwater. In addition, residents may not recognize these areas as the headwaters of streams, and the role they can play in reducing flooding downstream. Sharing this information with residents could be a part of a larger project to improve these watersheds.

The mouth of the Tannery Brook is enclosed in a pipe that is part of the Esopus Creek's flood control project. Given the high level of engineering in this area, interventions may be challenging. However, the large parking lot and sprawling buildings could be improved with vegetation and other features that could improve stormwater management and also provide other benefits, like shading, beautification, etc.

Although most actions to improve the brook would likely take place in its watershed, given the high connectivity to the storm sewer system, there are also opportunities along the stream channel. Riparian buffer restoration or even stream daylighting in certain locations could improve habitat, water quality, and aesthetics.

Although stream daylighting is a major undertaking, it is not unprecedented in the Hudson Valley. Local examples include Saw Mill River daylighting in Yonkers, a large-scale project that replaced a parking lot with a free-flowing river and public park (Trice 2013). At a much smaller scale, a small unnamed stream daylighting project took place in a public park in New Paltz (Quinn 2013). Stream daylighting is included as a green infrastructure practice in the NYS Stormwater Management Design Manual, and could be another tool for cities to improve water management (NYS DEC 2015).

Although it is extremely small compared to its receiving waterbody, the Tannery Brook could help contribute to improving the Esopus Creek. The Tannery Brook could play a larger role in delivering clean water to the Esopus Creek, and reducing loads of sediment and phosphorus. These are known and documented causes of impairment for the Esopus Creek (NYS DEC 2016). Water quality and flooding problems at a larger scale should take into account cumulative impacts from small streams, as it all adds up (Freeman et al. 2007). To identify and prioritize potential opportunities, it would be helpful to plan at a watershed scale for both the Tannery Brook and Main Street Brook.

In our modern-day economy that values quality of life and a sense of place, the Tannery Brook may still have something to offer. Even in its current neglected state, it still functions as a stream. Urban streams could provide ecosystems services including flood protection, aquatic habitat, nutrient retention, and a sense of place (Grimm et al. 2008). Current social dynamics in Kingston include gentrification, people working remotely, and the desirability of walkable, compact, mixed-used development. There are opportunities to manage flooding, improve water quality, and have the stream serve as an attract natural resource for the City of Kingston. However, people need to see and recognize the Tannery Brook as a stream before they care about it, or take any actions to improve it.

4.5 CONCLUSION

Small urban streams are increasingly rare. The legacy of piping and burying streams has removed them from the surface of urban areas, and we aren't used to seeing or dealing with small streams in cities (Trice 2013). Julia Farr from the Kingston Land Trust remarked how unusual it was to see a stream like the Tannery Brook in Kingston, and how she was really draw to it (Farr, personal communication, March 3, 2018).

We have inherited land use decisions made over the centuries, and these should inform future directions as we continue to work on issues of urban water quantity and quality. Impacts to rivers are cumulative over centuries, and not isolated (Dufour & Piegay 2009). A historical perspective gives a sense of the individuals behind the decision-making. People have always made decisions based on their values, with the best available information they have. We may have more information or better tools to manage water in urban areas in the future than we do today, but there is still so much to learn and understand. This perspective allows for a sense of humility in our current best practices.

The burden of managing urban streams has fallen on municipalities, especially as streams have increasingly become part of water infrastructure, even though the impacts come from residents, businesses, and land use throughout the watershed (Trice 2013). There is a need to talk to residents about the role they play in improving urban streams, and identify opportunities on private as well as public land.

Due to the complex underground storm sewer connections, the Tannery Brook's watershed is very difficult to delineate, and topographic tools do not tell the full story of how water flows in this landscape. Fragmentation created surprising new connections, like the inter-basin transfer of the Tannery Brook to Twaalfskill. Traditional watershed planning methods like using land use/land cover data to understand pollutant loading or topography to delineate watershed boundaries miss key information that is critical for understanding urban streams (Kaushal & Belt 2012). Land surface data may not be available at a high enough resolution for urban streams, and the configuration of the drainage system can impact urban streams more than percent impervious surface cover alone (Kaushal & Belt 2012, Vietz et al. 2016).

Urban streams may require different methods for planning and management, including detailed records of below-ground infrastructure. Yocom (2014) recommended that historical, place-based, local, community knowledge be built into river restoration plans and designs.

Changes in urban landscapes directly relate to culture; these are the sociological, ecological, economic, and philosophic values of the community (Kaushal & Belt 2012, Marcucci 2000, Yocum 2014). Buildings, landscaping, and aging infrastructure are constantly changing, and baselines are constantly shifting (Kaushal & Belt 2012).

We should rethink word choices like “restoration” or “recovery” as we also rethink the process of managing urban streams to meet our current cultural values and expectations (Dufour & Piegay 2009). Like green infrastructure design, urban stream management is about trade-offs. Rivers are “damaged” because we have prioritized other urban processes like industrialization, suburbanization, etc. over ecosystem services (Dufour & Piegay 2009). It is not realistic to set targets for improvements based on previous baselines, which have shifted considerably over the years. Instead, we need to understand current conditions, the historical context that created these conditions, and identify opportunities for the future based on our cultural values. It may be helpful to think about intentionally designed aquatic ecosystems, rather than “restoration” of these systems (Grimm et al. 2008).

Moving forward, we should be intentional about settling objectives for urban streams that recognize how our cultural values shape these waterways. This type of process can also help identify what is sustainable and reasonable to expect, and how to bring complex natural and cultural systems together (Dufour & Piegay 2009). It may not be reasonable to expect that a small urban streams could support the level of development we desire in a small city, and also provide high quality habitat and water quality. Urban streams are frequently designed to meet conflicting goals related to sanitation, industrial processes, and protection from natural disasters (Grimm et al. 2008). However, we can think creatively about functions that small urban streams can effectively provide to support habitat and environmental benefits for natural and cultural systems. Cities in particular are known for creativity and industry, and those positive attributes can help identify solutions for urban problems (Grimm et al. 2008).

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CHAPTER 5

CONCLUSION

5.1 PLACING GREEN INFRASTRUCTURE IN CONTEXT

How does a buried stream's history relate to current stormwater management practices? By recognizing what a stream used to provide, and what a place used to be, we can better assess our current-day values, and see how those could relate to urban stream and watershed management. An understanding of previous decisions can help us place our current technologies in context. Looking back can inform us as we plan for the future and consider how to live with water in cities.

The green infrastructure practices installed in 2016 represented a marked changed in approach to water management. Green infrastructure goals to reduce stormwater flows to "pre-development hydrology" are unreasonable, but there may still be opportunities to improve conditions (Dufour & Piegay 2009, NYS DEC 2015, Vietz et al 2016). The Tannery Brook's history could be told as a process of fragmentation until the stream was unrecognizable, and most water infrastructure contributed to that process. However, more recent water infrastructure forms like green infrastructure can play a very different role. Green infrastructure practices disconnect impervious surfaces, while reconnecting groundwater and baseflow vertically.

We are not used to seeing water in cities, as infrastructure (drinking water, wastewater, and stormwater) is below ground and streams have been buried. Water may move across the urban landscape in confounding ways. Green infrastructure brings water back to the surface, and allows people to see and interact with it in a different way. By telling the story of an urban stream's history, we can also bring that water back to the surface and raise consciousness of it.

Water management can be understood at scales from minutes to centuries, from a small rain garden to a broad and complex urban watershed. Data and technical information explain hydrologic processes, as do observations, stories, and peoples' lived experiences. Different approaches to communicating with and engaging diverse stakeholders can help municipalities and community groups work towards solutions to the complex problems faced by urban streams. Urban streams are impacted by actions taken across the watershed and residents need to understand the part they play. There is a large opportunity for the humanities, including history and art, to describe water issues and technical problems. Urban planning at various spatial and temporal scales needs to include people and cultural systems (Dufour & Piegay 2009).

Using history as an entry point is one method to engage different stakeholders in environmental planning, in particular by allow citizens to be experts (Marcucci 2000). It allows for a framing and grounding of current environmental issues (Marcucci 2000). Raising awareness of buried streams to increase community involvement and reconnect people to rivers was one of the top recommendations of a daylighting report by American Rivers (Trice 2013). Buried stream maps can also help residents understand where streams are located in the community, and provide a sense of place within a watershed (Trice 2013). Streams may not be on current-day maps, but may be causing problems that could be mitigated.

Art and history are innovative tools to tell stories and share data to new audiences, and these stakeholders can play a part in improving urban water resource management. Residents play a large role in managing properties within the watershed, but also in providing political pressure to allocate municipal resources in particular directions (for example, reducing flooding). Information on green infrastructure performance and urban stream management can be shared with different audiences in different ways to increase their understanding and capacity to enact change (Helicon Collaborative 2018). Art is a powerful medium to share information, tell stories, and enhance public engagement in a more meaningful way. These methods also allow participants to share their observations and stories, which can be critical to supplement technical data.

5.2 ART AS PUBLIC ENGAGEMENT ON WATER ISSUES

Fragmented & Forgotten at the Lace Mill

From March 3 to April 29, 2018, an exhibit on the Tannery Brook was on display at the Lace Mill in Kingston. “Fragmented & Forgotten: Tracing the Tannery Brook” explored the evolving relationship between the Tannery Brook and the Kingston community over time, breaking up material chronologically into five eras. The Lace Mill was previously an abandoned, century-old factory that was converted in 2015 into 55 affordable rental units for artists by RUPCO, a local affordable housing nonprofit. The Lace Mill includes several shared gallery and work spaces for artist-residents. This combination of arts and history, and the large gallery space, provided an ideal setting for the exhibit.

Interpretive text on each of the eras took viewer through the exhibit, which included copies of 29 historic maps, 27 digitized maps, 41 historic photos and paintings, 14 modern-day photos, and 11 excerpts of primary source documents. The earliest map of the brook was from 1685, and the most recent was from 2014.

Jiamin (Jasmine) Chen, a graduate landscape architecture student from Cornell University, created a series of digitized maps, based on historic maps, to visualize changes in and around the Tannery Brook with a consistent set of symbology. Jasmine also assisted with curating the exhibit.

Approximately 185 people visited the Tannery Brook exhibit, including residents who live along the Tannery Brook, municipal officials and staff, local history experts, water management professionals, and many others. Although the show was originally planned to be up for one month, it was extended for another month due to local interest. The exhibit not only shared information about the Tannery Brook and its history, but it also created a space for people to gather and have conversations. People shared their knowledge and first-hand experiences with the brook, which added richness to the exhibit and helped identify opportunities for future work.

In addition to open viewing hours, several events were held in the space, including a green infrastructure in Kingston workshop, in partnership with City of Kingston and Ulster County Department of the Environment; a lecture on the history of the Tannery Brook; two jazz concerts organized by bassist Michael Bisio; and a Heal Well Kingston gathering, sponsored by the City of Kingston. This opened up the exhibit to many different people and groups that otherwise might not have seen it.

The green infrastructure in Kingston workshop on March 14, 2018 was an opportunity to share research findings on the North Front Street parking lots and green infrastructure practices. A more traditional outreach event, it featured presentations and case studies of green infrastructure projects from the City of Kingston and Ulster County Department of the Environment. It was attended by 25 environmental professionals, and included productive and practical conversations about opportunities for green infrastructure and lessons learned from previous installations. This workshop brought these technical experts into the art gallery space, which was a very different context for information-sharing. One of the engineers that attended followed up by sending a poem that describes buried streams (A Brook in the City by Robert Frost, 1923). The workshop was a multi-disciplinary experience that emphasized the importance of the arts.

As a result of the interest in the exhibit and the Tannery Brook, I created a website (https://www.tracingtannerybrook.com) to provide access to the information and maps, along with ways to get involved. For more information about "Fragmented & Forgotten: Tracing the Tannery Brook," including testimonials and photographs of the exhibit, see Appendix H.

Tracing the Tannery Brook at O+ Festival

As part of the O+ Festival in Kingston on October 6-7, 2018, I presented a site-specific, participatory installation on the Tannery Brook. The O+ Festival is a weekend festival of diverse music, arts, and wellness events in Kingston. Its mission is to empower communities to take control of their collective wellbeing through art, music, and wellness. Having this installation within the context of this festival helped reach new audiences, and contributed to an imaginative and beautiful final product.

The installation took place in the Ulster County Family Court parking lot at 16 Lucas Avenue, Kingston. The Tannery Brook was buried at this site, but is still visible and audible through storm drains in the parking lot. At the O+ installation, participants literally traced the Tannery Brook by marking the stream's path with chalk and chalk paint on the asphalt where it was buried. Over 60 people of all ages contributed to the "daylighting" by tracing and painting swirls and ripples to visualize a flowing threat through the parking lot. Homemade chalk paint (cornstarch, water, and tempera paint) and sidewalk chalk allowed for a temporary installation, and did not harm the stream when it washed away.

Participants were asked, "What would be here, if this were a healthy stream?" This was the only prompting needed, as both children and adults were enthusiastic about drawing on the asphalt. They contributed fish, frogs, turtles, wildlife, insects, flowers, trees, and people enjoying the stream. The process helped bring life back to the buried stream.

Participants also engaged with the existing water infrastructure in creative ways. One person drew a large arrow pointing to one of the stormdrains where you can see and hear the Tannery Brook, and wrote: "LISTEN." Poet Will Nixon added a haiku about water infrastructure next to two additional storm drains.

This process helped to re-imagine the urban landscape, and visualize the potential for a healthy stream in Kingston. The photos and videos are striking, and the installation brought life to a run-down parking lot and buried stream. The process helped participants think about urban streams, and photographs of the product can be used in the future to describe the potential for urban streams to improve.

As part of a larger wellness festival, the Tannery Brook brought environmental wellness to the conversation. Many management decisions around the Tannery Brook related back to public health, from draining the mill pond in 1807 to installing sewers in 1889. Today, we can think about community health more broadly, and include the health of Kingston’s environment and the Esopus Creek watershed.

In addition to the interactive component, there was also a display of historical materials. The local history component helped draw people in, and provided context for the tracing. This included six panels about the Tannery Brook’s history, organized by themes. These included wayfinding, agriculture, industry, infrastructure, flooding, and burial. The display included maps of the Tannery Brook from 1870 and 1888 at the Family Court site, where the stream was traced.

The installation also included other props to add meaning to the site. It displayed a real tanned deer hide, as a visual and tactile reminder of what tanneries produce. We also set out native trees and shrubs along the traced stream corridor to imitate a healthy riparian buffer. These plants were from the Hudson River Estuary Program’s Trees for Tribs initiative, which provides free native trees and shrubs to restore riparian buffers. The trees provided a vertical dimension to the two dimensional stream painting, and also helped initiative conversations about how vegetation along streams is beneficial.

According to American Rivers:

“Daylighting exists in several forms including: natural restoration – restoring a stream to natural conditions; architectural restoration – restoring a stream to open air, flowing water but within a constructed channel; or cultural restoration – celebration of a buried stream through markers or public art used to inform the public of the historic stream path, although the stream remains buried" (Trice 2013).

By sharing the Tannery Brook's story and celebrating its history, this work was a cultural daylighting to bring the stream out of the shadows – the 2018 O+ theme.

For more information about "Tracing the Tannery Brook," including photographs of the installation, see Appendix I.

5.3 CONCLUSION

The green infrastructure practices assessed Kingston's Uptown municipal parking lots reduced runoff very quickly. However, green infrastructure practices are dynamic, and performance could change over time. Based on frequent visual observations, a number of issues were identified at the site. These represent important lessons learned to improve green infrastructure design and maintenance urban areas. At a broader scale, the history of the Tannery Brook's watershed provides context for president-day opportunities, like green infrastructure. The Tannery Brook provided a compelling story for technical experts and local stakeholders alike, and is a local illustration of the impact that water management decisions can have over time.

Green infrastructure practices offer an opportunity to rethink water and nature in cities. They allow runoff to infiltrate and evapotranspire, rather than flow quickly to a storm sewer. They are not only visible infrastructure, but they can be attractive assets. There may be other opportunities to rethink other types of infrastructure as an attractive, visible asset to the community. Water infrastructure is difficult to imagine, but a large sinkhole or a public art installation can bring these concepts to the surface.

As we learn about past decisions, it can allow us to make more informed decisions moving forward.

We can't look to the past for stream restoration. Not only have systems been altered for centuries, and conditions outside of the stream channel have changed to an extent where restoration to a particular baseline is no longer realistic, our values have changed over time, as have our local economies. Instead, we should think creatively about opportunities to live with water in cities.

5.4 REFERENCES

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APPENDIX A:
Budgeted Cost for Uptown Parking Lots Green Infrastructure

From City of Kingston. 2013. "2013 Water Quality Improvement Projects Round 11 Application for State Assistance: Kingston Uptown Parking Area Green Infrastructure Project." Nonagricultural Nonpoint Source Abatement and Control.

Category of Expense	**Grant Funds**	**Match Funds**	**Total**	**Notes**
Personal Services				
Salary		$17,719.05	$17,719.05	15% salary for Environmental Educator 1/Project Manager, 10% salary for Environmental Educator 1, 10% salary for City Engineer
Fringe		$2,657.86	$2,657.86	15% Fringe
Subtotal		$20,376.91	$20,376.91	
Non-Personal Services				
Contractual Services	$365,831.00	$90,000.00	$455,831.00	See below for details
Travel				
Equipment		$12,000.00	$12,000.00	City DPW equipment use
Space/ Property & Utilities				
Operating Expenses				
Other				
Subtotal	$365,831.00	$102,000.00	$467,831.00	
TOTAL	$365,831.00	$122,376.91	$488,207.91	

Contractual Services - $455,831 total
General Contracting - $180,711.00
Electrical - $24,000.00
Excavation (Milling) - $26,000.00
Landscape and GI Construction Services - $214,920.00
Design - $10,200.00

APPENDIX B:
Test Pit Results for Uptown Parking Lots

From Barton & Loguidice. 2015. "Contract Drawings, City of Kingston Downtown Parking Lots." Contract 1: General Construction.

Test Pit 1 – North lot, southwest corner near entrance (post-construction: asphalt)

Depth	**Material**
0-8”	Asphalt
8-28”	Fill
28”	Old building foundation

Test Pit 2/Infiltration Test 2 – North lot, northeast side (post-construction: pervious pavers)
Stabilized infiltration rate: 72”/hr

Depth	**Material**
0-6”	Asphalt
6-7”	Stone
7-72”	Coarse sand

Test Pit 3/Infiltration Test 3 – South lot (post-construction: pervious pavers)
Stabilized infiltration rate: 19”/hr

Depth	**Material**
0-6”	Asphalt
7-13”	Crushed shale
13-37”	Construction fill
37-73”	Coarse sand

APPENDIX C:
Summary of Pre-Construction and Post-Construction Runoff

From Barton & Loguidice. 2015. "HydroCAD Modeling for Pre-Development and Post-Development Northern & Southern Parking Lots." *SWPPP Appendix D.*

South Lot

The runoff area within the parking lot was 32 ft^2 smaller after construction. Runoff volume and peak flow runoff were reduced across the parking lot.

South Lot

Recurrence Interval	Storm Size (in)	Pre- or Post-construction	Runoff Area (ft^2)	Runoff Volume (af)	Peak Flow Runoff (cfs)
WQv	2.0	Pre	38,045	0.241	2.62
		Post	38,013	0.111	2.36
		DIFFERENCE	-32	-0.130	-0.26
10 year	4.69	Pre	38,045	0.325	6.30
		Post	38,013	0.301	6.04
		DIFFERENCE	-32	-0.024	-0.26
100 year	8.31	Pre	38,045	0.587	11.19
		Post	38,013	0.650	10.98
		DIFFERENCE	-32	0.063	-0.21

North Lot

The runoff area within the parking lot stayed the same size (27,452 ft^2), but removed 2,472 ft^2 of impervious cover. Runoff volume and peak flow runoff were reduced across the parking lot.

North Lot

Recurrence Interval	Storm Size (in)	Pre- or Post-construction	Runoff Area (ft^2)	Runoff Volume (af)	Peak Flow Runoff (cfs)
WQv	2.0	Pre	27,452	0.093	1.83
		Post	27,452	0.069	1.5
		DIFFERENCE	0	-0.024	-0.33
10 year	4.69	Pre	27,452	0.559	4.39
		Post	27,452	0.197	4.15
		DIFFERENCE	0	-0.362	-0.24
100 year	8.31	Pre	27,452	0.424	7.81
		Post	27,452	0.381	7.81
		DIFFERENCE	0	-0.043	0

Both Lots, Total Pre-Construction values minus post-construction values

Recurrence Interval	Storm Size (in)	Runoff Area (ft^2)	Runoff Volume (af)	Peak Flow Runoff (cfs)
WQv	2.0	-32	-0.154	-0.59
10 year	4.69	-32	-0.386	-0.50
100 year	8.31	-32	0.020	-0.21

APPENDIX D:
General Green Infrastructure Specifications

Specifications and images from: Barton & Loguidice. 2015. "Contract Drawings, City of Kingston Downtown Parking Lots." Contract 1: General Construction.

Note: These designs did not separate rain gardens from bioretention areas in the specifications, and they did not include a diagram of a rain garden without an underdrain in the details.

Bioretention Areas

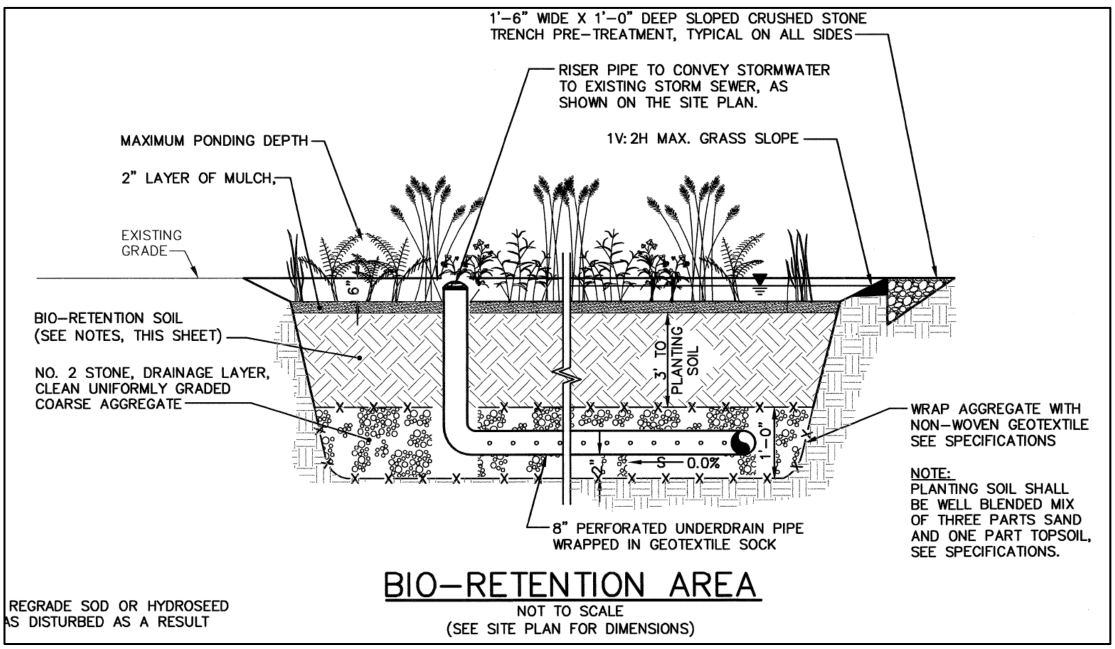
1'-6" wide x 1'-0" deep sloped crushed stone trench pre-treatment, typical on all sides
1V:2H max. grass slope
Riser pipe to convey stormwater to existing storm sewer, as shown on the site plan
6" from top of mulch to existing grade
2" layer of mulch
3' bioretention soil to planting soil. Note: Planting soil shall be well blended mix of three parts sand and one part topsoil, see specifications.
Below that, 1' of No. 2 stone, drainage layer, clean uniformly graded coarse aggregate. Wrap aggregate with non-woven geotextile.
8" perforated underdrain pipe wrapped in geotextile sock, underdrain has 0.0% slope (is raised above bottom of aggregate, doesn't show how much)

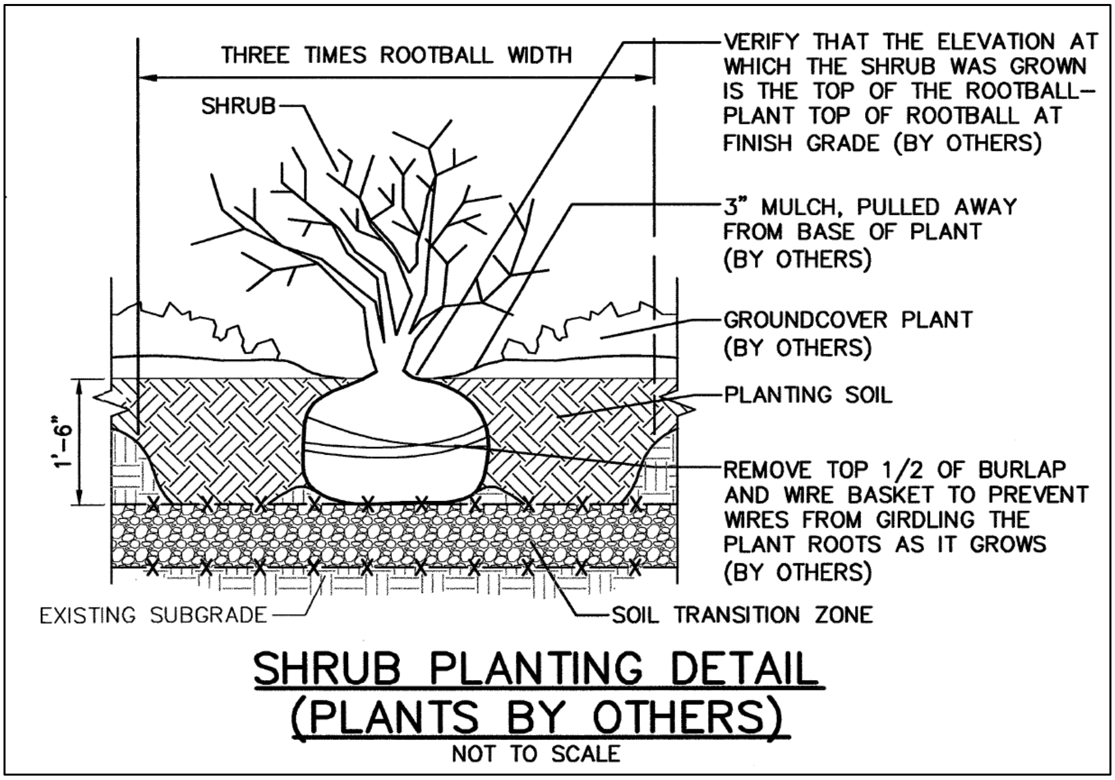
Notes on plant materials:

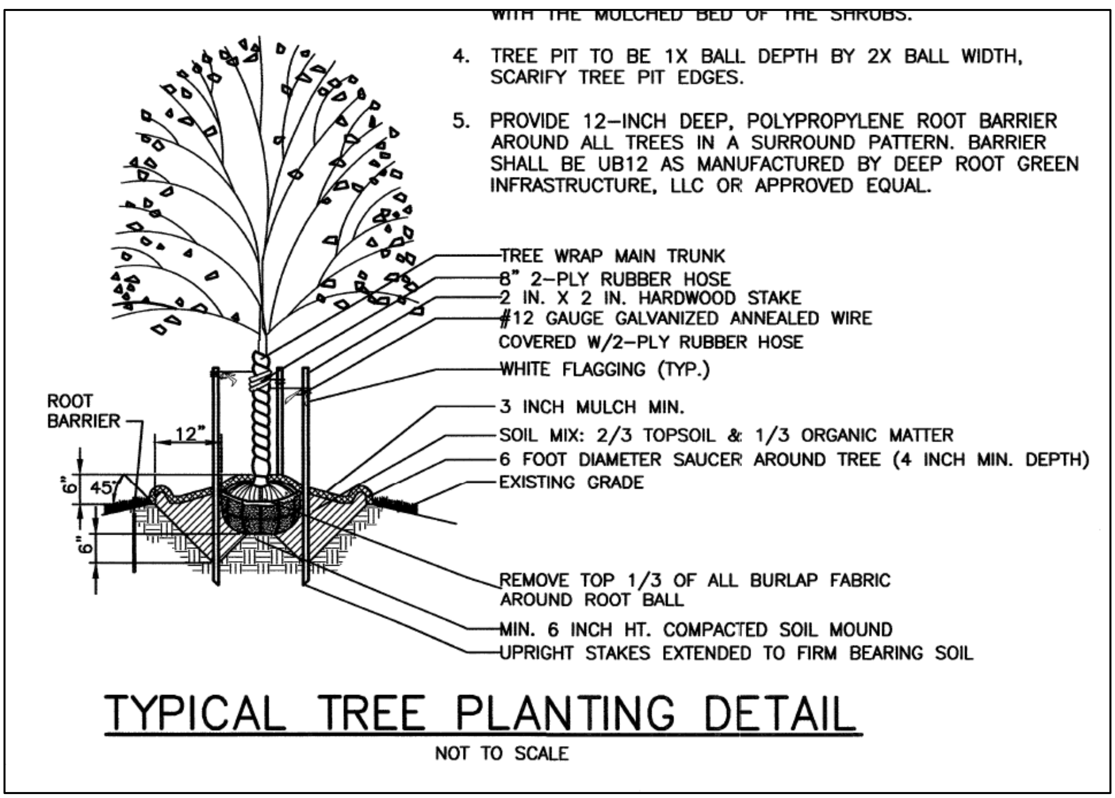
1. All plants, unless otherwise specifically permitted, shall conform to the standards of the current edition of American standard for nursery stock as approved by the American Standards Institute, Inc. All plant grades shall be those established in the current edition of American Standards for nursery stock. Only one size per grade will be listed rather than a size range. The one size shall mean the minimum size for that grade and shall include plants from that size up to but not including the larger grade size.
2. All plant materials shall have normal, well developed branches a vigorous root system. They shall be healthy plants free from physical defects, plant diseases, and insect pests. Shade and flowering trees shall be symmetrically balanced. Major branches shall not have V shaped crotches capable of causing structural weakness. Trunks shall be free of unhealed branch removal wounds greater than a 1 in. diameter.
3. Water used in the planting, establishing or caring for vegetation shall be free from any substance that is injurious to plant life. Payment will not be made for water used.
4. Tree and stormwater planter plants will be measured and paid for as part of the lump sum cost of the project. If at any time during the 1-year warranty period any plants become unacceptable, they shall be replaced at no additional cost to the owner.

Tree planting notes:

1. Landscape contractor to regrade sod or hydroseed and straw mulch all areas disturbed as a result [of] construction.
2. Upright stakes to be used on trees up to 12 ft. in height. Larger trees must be guyed.
3. Trees which are located within 4 ft. of an adjacent shrub bed shall have their mulched area connected with the mulched bed of the shrubs.
4. Tree pit to be 1x ball depth by 2x ball width, scarify tree pit edges.
5. Provide 12-inch deep, polypropylene root barrier around all trees in a surround pattern. Barrier shall be UB12 as manufactured by deep root green infrastructure, LLC or approved equal.




THREE TIMES ROOTBALL WIDTH
SHRUB
VERIFY THAT THE ELEVATION AT WHICH THE SHRUB WAS GROWN IS THE TOP OF THE ROOTBALL–PLANT TOP OF ROOTBALL AT FINISH GRADE (BY OTHERS)
3" MULCH, PULLED AWAY FROM BASE OF PLANT (BY OTHERS)
GROUNDCOVER PLANT (BY OTHERS)
PLANTING SOIL
1'-6"
REMOVE TOP 1/2 OF BURLAP AND WIRE BASKET TO PREVENT WIRES FROM GIRDLING THE PLANT ROOTS AS IT GROWS (BY OTHERS)
EXISTING SUBGRADE
SOIL TRANSITION ZONE
SHRUB PLANTING DETAIL
(PLANTS BY OTHERS)
NOT TO SCALE


WITH THE MULCHED BED OF THE SHRUBS.
4. TREE PIT TO BE 1X BALL DEPTH BY 2X BALL WIDTH, SCARIFY TREE PIT EDGES.
5. PROVIDE 12-INCH DEEP, POLYPROPYLENE ROOT BARRIER AROUND ALL TREES IN A SURROUND PATTERN. BARRIER SHALL BE UB12 AS MANUFACTURED BY DEEP ROOT GREEN INFRASTRUCTURE, LLC OR APPROVED EQUAL.
TREE WRAP MAIN TRUNK
8" 2-PLY RUBBER HOSE
2 IN. X 2 IN. HARDWOOD STAKE
#12 GAUGE GALVANIZED ANNEALED WIRE COVERED W/2-PLY RUBBER HOSE
WHITE FLAGGING (TYP.)
ROOT BARRIER
12"
3 INCH MULCH MIN.
SOIL MIX: 2/3 TOPSOIL & 1/3 ORGANIC MATTER
6 FOOT DIAMETER SAUCER AROUND TREE (4 INCH MIN. DEPTH)
EXISTING GRADE
6"
45°
6"
REMOVE TOP 1/3 OF ALL BURLAP FABRIC AROUND ROOT BALL
MIN. 6 INCH HT. COMPACTED SOIL MOUND
UPRIGHT STAKES EXTENDED TO FIRM BEARING SOIL
TYPICAL TREE PLANTING DETAIL
NOT TO SCALE

Photos of 8” perforated HDPE pipes for the bioretention underdrains and underdrains connecting dry wells during construction of the South lot (August 13, 2016).

Dry Wells

Top: Syracuse frame and grate no. 2816A
Adjustment rings as required, and below that 8” precast cover (traffic). 1’ minimum between precast cover and finished grade
8’ O.D. precast concrete dry well
Inlet pipe brings water into dry well, 90 degree elbow that stops 12” from the bottom of crushed stone base. 18” square x 6” thick minimum splash block of a hard, durable, single native stone right below elbow.
Surrounding dry well (3’ minimum), 1-1/2” – 1-1/2” crushed stone complying with NYSDOT item 623.12. Surround stone with geotextile drainage (overlap seams 8” min)
8” x 12”W precast footing at bottom of concrete dry well, 6” crushed stone base below that
Below concrete dry well, crushed stone base above native material layer. Do not compact subgrade. No fabric at subgrade.

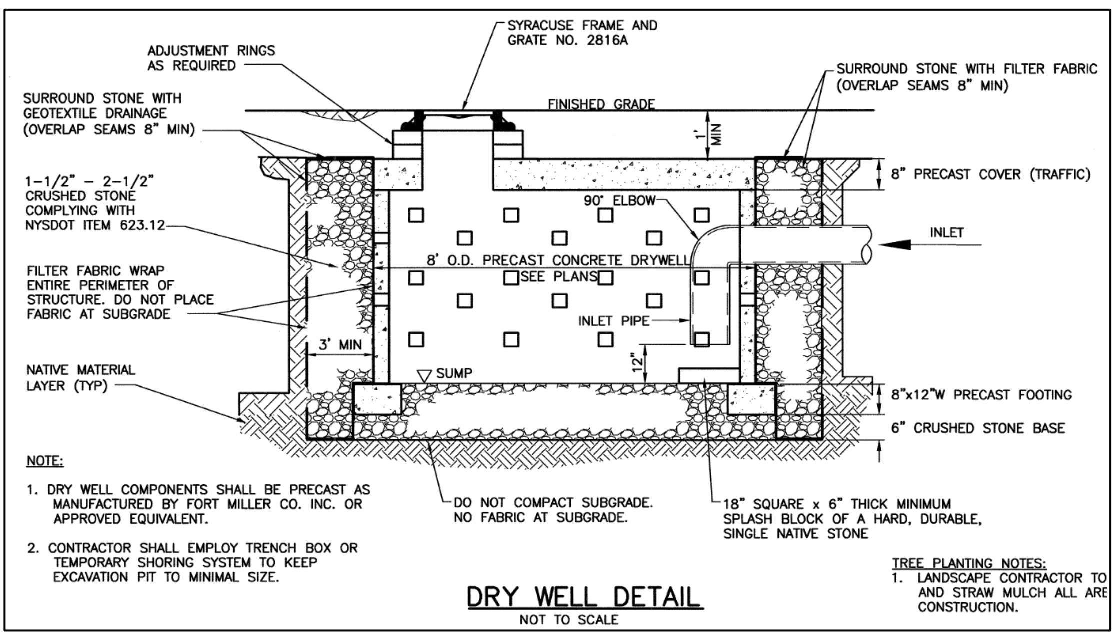


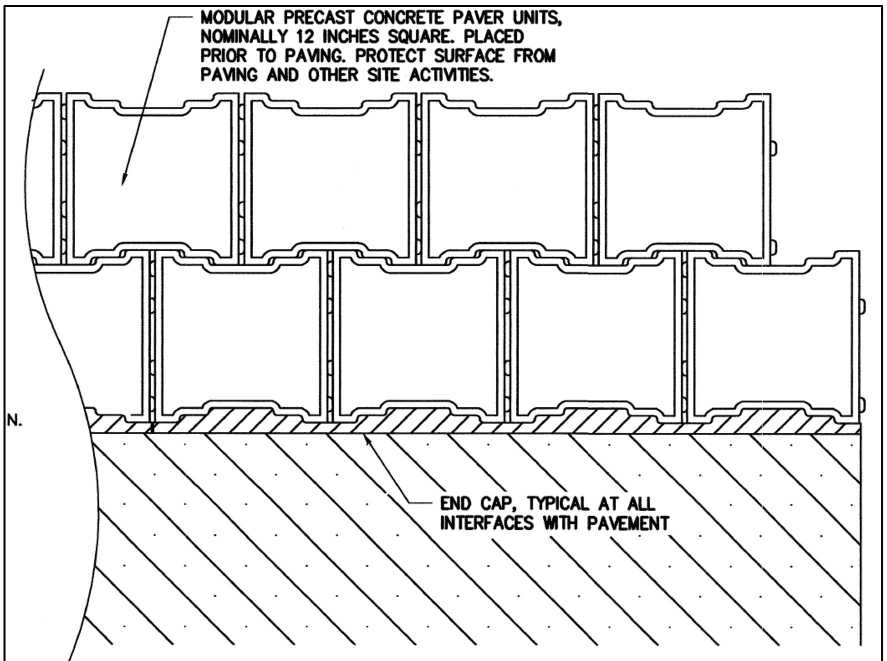
Photo of 8’ diameter dry wells during construction of the South lot (August 3, 2016).

Photo of 8’ diameter dry well during construction of the South lot (August 3, 2016).

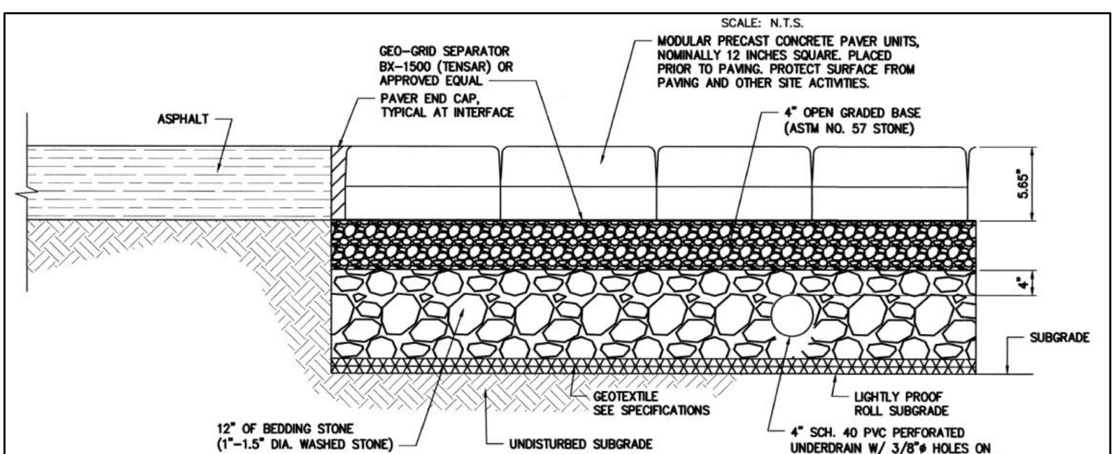
Photo of 8’ diameter dry well during construction of the North lot (September 21, 2016).

Pervious Pavers

Modular precast concrete paver units, nominally 12 inches square. Placed prior to paving, protect surface from paving and other site activities.
End cap, typical at all interfaces with pavement.
Concrete pavers 5.65” tall, then geo-grid separator BX-1500 (Tensar) or approved equal, then 4” open graded base (ASTM No. 57 stone), then 12” of bedding stone (1”-1.5” dia. Washed stone), then geotextile (“see specifications”), then undisturbed subgrade.
Within the 12” of bedding stone – 4” down from base is underdrain – “4” sch. 40 PVC perforated underdrain with 3/8” holes on 12” centers at 5 and 7 o’clock



MODULAR POROUS CONCRETE PAVER PLAN
SCALE: N.T.S.



MODULAR POROUS CONCRETE PAVER SECTION
SCALE: N.T.S.

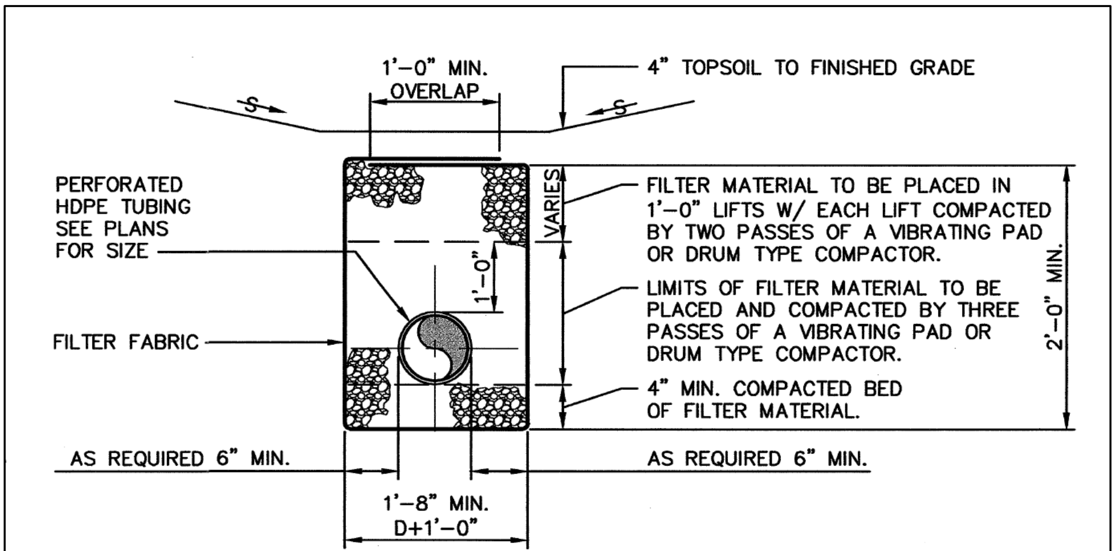
Photo of 4” PVC pipes for the pervious paver underdrains during construction of the South lot (August 3, 2016).

Photo of concrete block pervious pavers during construction of the South lot (August 11, 2016).

Miscellaneous

Concrete curb detail – “Finish grade 1” below top of curb in all landscaped areas”

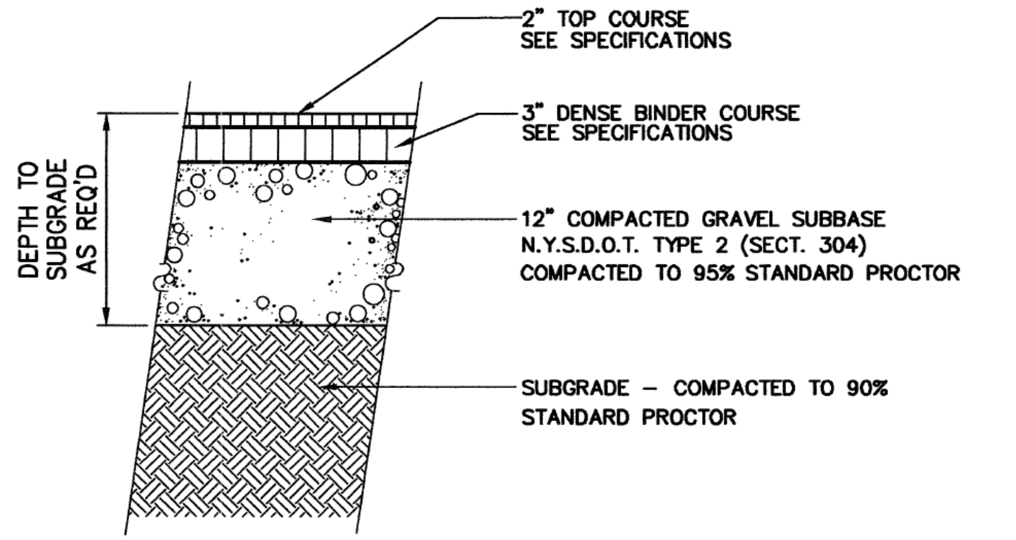
Underdrain specs
4” topsoil to finished grade
1’-0” min. overlap
Underdrain is perforated HDPE tubing
Filter material to be placed in 1’-0” lifts w/ each lift compacted by two passes of a vibrating pad or drum type compactor.
Limits of filter material to be placed and compacted by three passes of a vibrating pad or drum type compactor.
4” min. compacted bed of filter material (below underdrain)
As required 6” min.
1’-8” min. D+1’-0”



TYPICAL UNDERDRAIN DETAIL

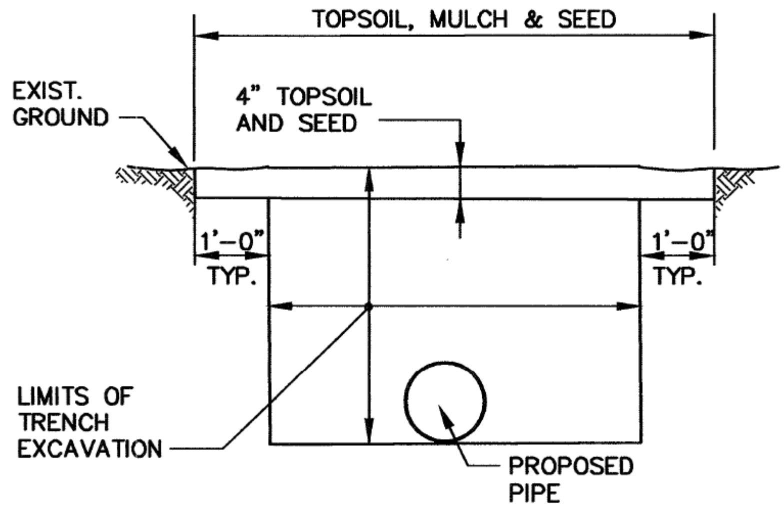
NOT TO SCALE

Asphalt parking lot section
2” top course see specifications
3” dense binder course see specifications
12” compacted gravel subbase N.Y.S.D.O.T. Type 2 (Sect. 304) compacted to 95% Standard Proctor
Subgrade – compacted to 90% Standard Proctor



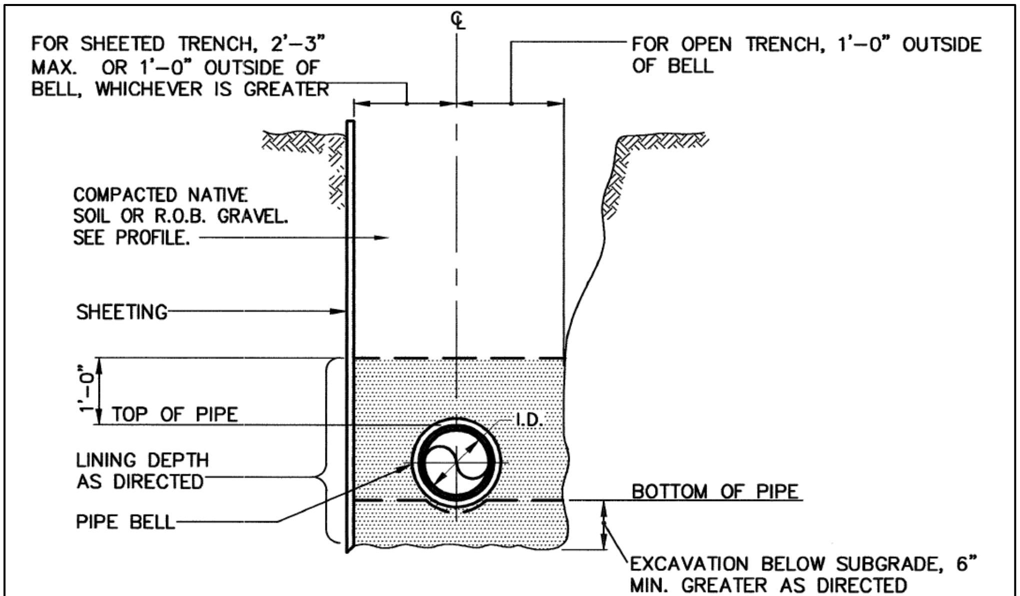
ASPHALT PARKING LOT SECTION

NOT TO SCALE



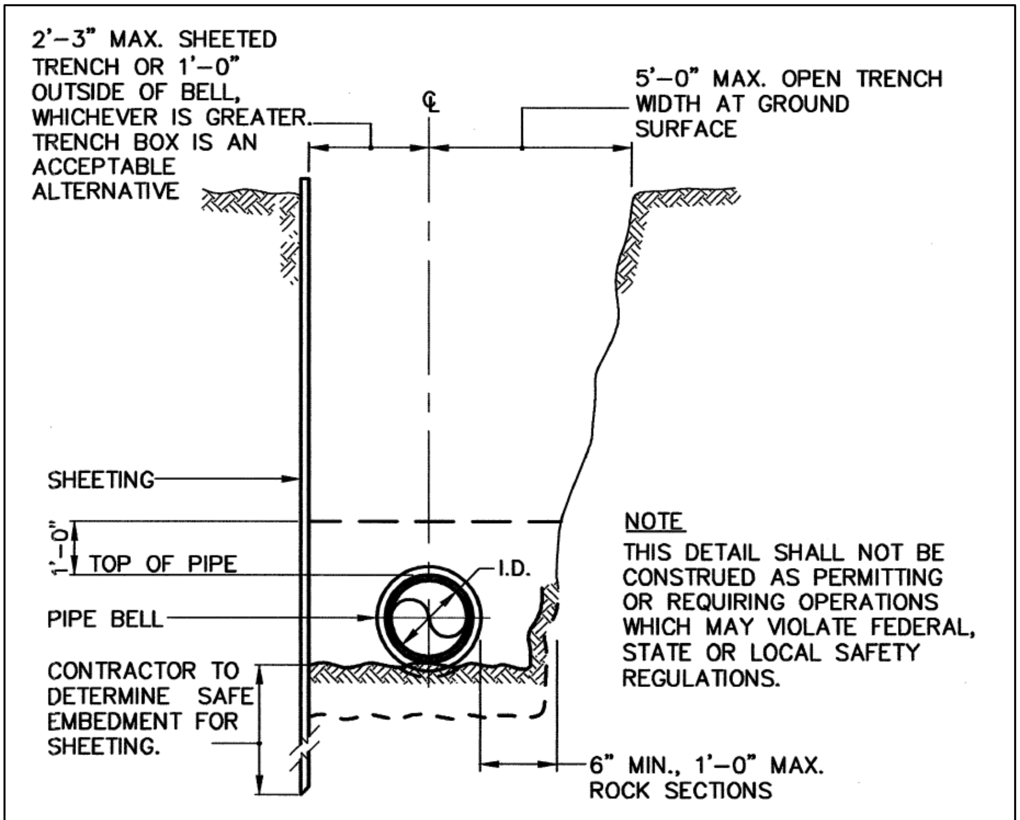
LAWN AND SLOPE RESTORATION

SCALE: N.T.S.



LIMITS FOR EXCAVATION BELOW SUBGRADE AND LINING

SCALE: N.T.S.



LIMITING WIDTHS OF TRENCH

SCALE: N.T.S.

APPENDIX E:
Statistics and Characteristics of Individual Green Infrastructure Practices

Design values from: Barton & Loguidice. 2015. "HydroCAD Modeling for Pre-Development and Post-Development Northern & Southern Parking Lots." *SWPPP Appendix D.*

Specifications from: Barton & Loguidice. 2015. "Contract Drawings, City of Kingston Downown Parking Lots." Contract 1: General Construction. August.

Rain Garden North

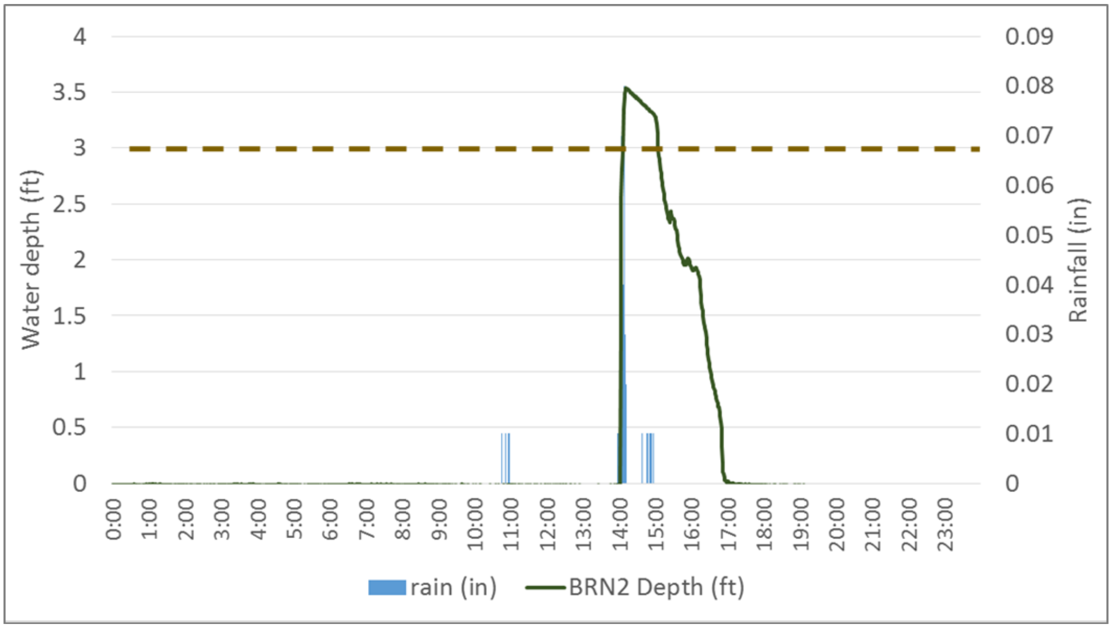
Linear rain garden along the west side of the North parking lot, between that parking lot and the asphalt lot of the adjacent property. No underdrain. Any overflow is designed to overflow to the north of the site, down the slope.

June 19, 2017

Practice	Designed Storage (ft^3)	Designed Drainage Area (ft^2)	# of storms recorded	# of storms w/ response
Rain Garden North	253	4,124	28	20

	Min	Mean	Median	Max
Max water depth (ft)	0	1.584	1.349	3.534 (8/4/17)
Time to drain (hrs)	0.17	3.31	2.90	8.23* (9/6/17)

*actually drains down fully between peaks. 2nd longest time to drain is 7.55 hours, from the storm that began on 8/11/17.



Example of water level in Rain Garden North during storm on August 4, 2017 (0.62 inches, most intense storm during study). The dashed line represents the soil surface (HOBOs were buried 3 feet into the soil), and water level above the line indicates ponding.

Dimensions from engineering plans:
Area bottom elevation: 176.90
Grass lined swale 18” bottom width with 1V:3H grassed side slopes

Drainage paths:
100 ft sheet flow, slope = 0.01 ft/ft
25 ft shallow conc. flow, slope = 0.01 ft/ft
Area = 4,124 sf
Green = 1,375 sf

Inflow area = 0.095 ac
Total available storage = 253 cf
Time of concentration = 1.7 min
Impervious = 2,749 sf, 66.66%
Pervious = 1,375 sf, 33.34%, Brush, Good, HSG A
Weighted CN = 75

Rain Garden North Plantings

QTY	SYM	"BOTANICAL NAME COMMON NAME"	SIZE	ROOT	MIN. SPACING	REMARKS
TREES AND SHRUBS						
1	AC	"AMELANCHIER CANADENSIS SHADOWBUSH, SERVICEBERRY"	6' HT	B&B	36" O.C.	
1	CO	"CEPHALANTHUS OCCIDENTALIS BUTTONBUSH"	1 GAL	CONT.	24" O.C.	MOUNDED
2	MY	"MYRICA PENSYLVANICA BAYBERRY"	1 GAL	CONT.	36" O.C.	AT LEAST ONE MALE & FEMALE REQ'D
1	VD	"VIBURIUM DENTATUM ARROWWOOD VIBURIUM"	36" HT	B&B	15' O.C.	
PERENNIALS AND ORNAMENTAL GRASSES						
4	AG	"AGROSTIS ALBA REDTOP"	1 GAL.	CONT.	48" O.C.	CLUMP FORM
8	AS	"ANDROPOGON SCOPARIUS LITTLE BLUESTEM"	1 GAL	CONT.	24" O.C.	CLUMP FORM
10	CL	"CHASMANTHIUM LATIFOLIUM NORTHERN SEA OATS"	1 QT	CONT.	12" O.C.	CLUMP FORM
6	CV	"CAREX VULPINOIDEA FOX SEDGE"	1 QT	CONT.	12" O.C.	CLUMP FORM
200 SF	LO	"LOTUS CORNICULATUS BIRDFOOD DEERVETCH"	SEED		0.2 LB/1,000 SF	
6	PA	"PANICUM VIRGATUM SWITCHGRASS"	1 QT	CONT.	18" O.C.	CLUMP FORM
6	RF	"RUDBECKIA FULGIDA BLACK EYED SUSAN"	1 GAL	CONT.	12" O.C.	CLUMP FORM

Rain Garden South

Deep, triangular rain garden along the side of the South parking lot, between the lot and a bluestone sidewalk along Crown Street. No underdrain.

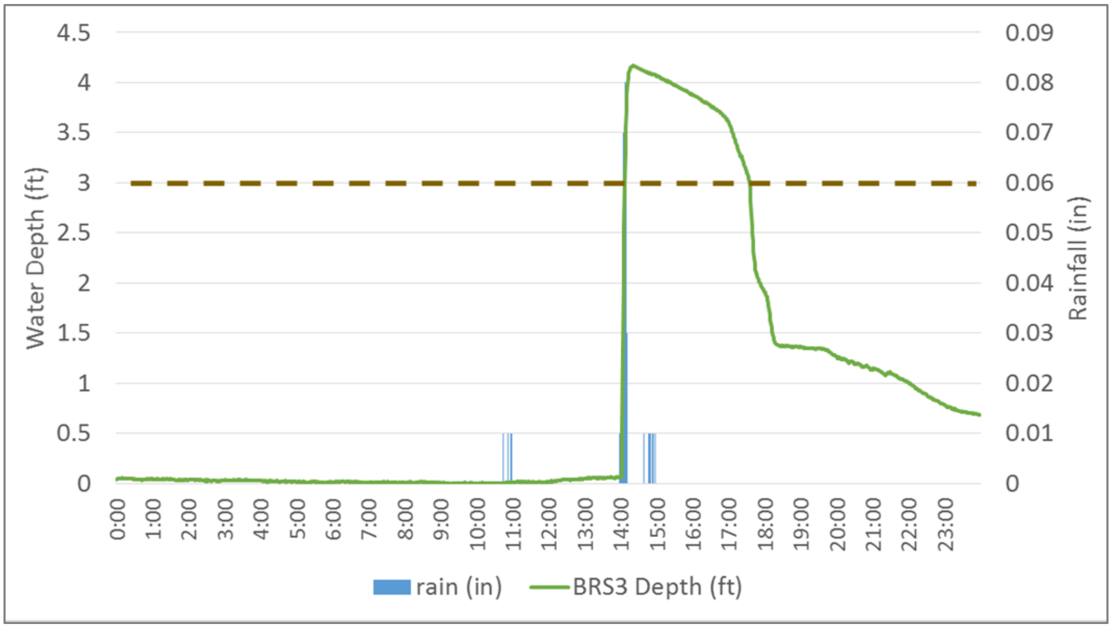
June 19, 2017

Practice	Designed Storage (ft^3)	Designed Drainage Area (ft^2)	# of storms recorded	# of storms w/ response
Rain Garden South	157	734	28	22

Max water depth (ft)

	Min	Mean	Median	Max
Max water depth (ft)	0	2.009	2.549	4.168
Time to drain (hrs)	1.05	15.01	11.81	65.25* (5/5/17)

*Another storm began before the practice finished draining. (This storm began 5/5/17.) 2^{nd} longest time to drain is 25.98 hours on 7/2/17.



Example of water level in Rain Garden South during storm on August 4, 2017 (0.62 inches, most intense storm during study). The dashed line represents the soil surface (HOBOs were buried 3 feet into the soil), and water level above the line indicates ponding.

Dimensions from engineering plans:
Bottom elevation: 179.3
Adjacent asphalt elev: 180.3
No underdrain
Rain Garden South Plantings

QTY	SYM	"BOTANICAL NAME COMMON NAME"	SIZE	ROOT	MIN. SPACING	REMARKS
PERENNIALS AND ORNAMENTAL GRASSES						
4	CV	"CAREX VULPINOIDEA FOX SEDGE"	1 QT	CONT.	12" O.C.	CLUMP FORM
4	PA	"PANICUM VIRGATUM SWITCHGRASS"	1 QT	CONT.	18" O.C.	CLUMP FORM
4	RF	"RUDBECKIA FULGIDA BLACK EYED SUSAN"	1 GAL	CONT.	12" O.C.	CLUMP FORM

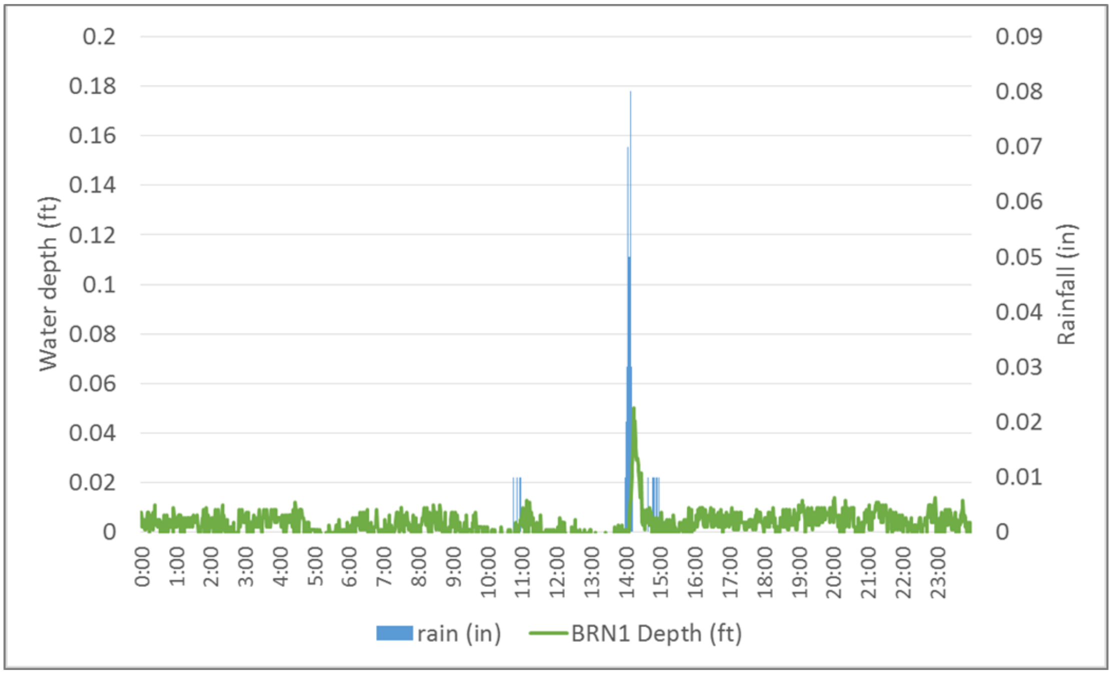
Bioretention Area North

Long bioretention area on the south edge of the North parking lot, between the lot and the sidewalk on North Front St. Underdrain with 2 overflow risers. The overflow riser containing the HOBO was nearly flush to the surface, not raised 6” as per the original designs. This bioretention area was the only one that received mulch, and had very little depression to store water.

June 19, 2017

Practice	Designed Storage (ft^3)	Designed Drainage Area (ft^2)	# of storms recorded	# of storms w/ response
Bioretention North	410	2,765	28	9

	Min	Mean	Median	Max
Max water depth (ft)	0	0.017	0	0.100 (5/6/17)
Time to drain (hrs)	0.05	1.88	1.70	5.83 (8/11/17)



Example of water level within the underdrain of Bioretention Area North during storm on August 4, 2017 (0.62 inches, most intense storm during study). The maximum depth during this storm was 1.2 inches.

Dimensions from engineering plans:
Bottom elevation: 178.0
8” outlet pipe risers at 178.45
8” underdrain to driving lane dry well; 152 LF 8” HDPE UD 0.6%
8” TEE INV: 173.92
Remove drop curb, sloped concrete ramp and replace with new concrete curb to match existing reveal. Replace concrete sidewalk.
Underdrain connects to Dry Well N 1

From drainage paths map:
Area = 2,765 sf
Green = 823 sf
34 ft sheet flow, slope = 0.01 ft/ft

Inflow area = 0.063 ac
Total available storage = 410 cf
Time of concentration = 0.7 min
Impervious = 1,942 sf, 70.24%
Pervious = 823 sf, 29.76%, Brush, Good, HSG A
Weighted CN = 78

Bioretention North Plantings

QTY	SYM	"BOTANICAL NAME COMMON NAME"	SIZE	ROOT	MIN. SPACING	REMARKS
TREES AND SHRUBS						
2	AC	"AMELANCHIER CANADENSIS SHADOWBUSH, SERVICEBERRY"	6' HT	B&B	36" O.C.	
1	CO	"CEPHALANTHUS OCCIDENTALIS BUTTONBUSH"	1 GAL	CONT.	24" O.C.	MOUNDED
3	MY	"MYRICA PENSYLVANICA BAYBERRY"	1 GAL	CONT.	36" O.C.	AT LEAST ONE MALE & FEMALE REQ'D
1	VD	"VIBURIUM DENTATUM ARROWWOOD VIBURIUM"	36" HT	B&B	15' O.C.	
PERENNIALS AND ORNAMENTAL GRASSES						
6	AG	"AGROSTIS ALBA REDTOP"	1 GAL.	CONT.	48" O.C.	CLUMP FORM
10	AS	"ANDROPOGON SCOPARIUS LITTLE BLUESTEM"	1 GAL	CONT.	24" O.C.	CLUMP FORM
16	CL	"CHASMANTHIUM LATIFOLIUM NORTHERN SEA OATS"	1 QT	CONT.	12" O.C.	CLUMP FORM
8	CV	"CAREX VULPINOIDEA FOX SEDGE"	1 QT	CONT.	12" O.C.	CLUMP FORM
200 SF	LO	"LOTUS CORNICULATUS BIRDFOOD DEERVETCH"	SEED		0.2 LB/1,000 SF	
10	PA	"PANICUM VIRGATUM SWITCHGRASS"	1 QT	CONT.	18" O.C.	CLUMP FORM
10	RF	"RUDBECKIA FULGIDA BLACK EYED SUSAN"	1 GAL	CONT.	12" O.C.	CLUMP FORM

Bioretention Area South 1

Linear bioretention area on the north edge of the South parking lot, between the lot and the sidewalk on North Front St. The downspout from an adjacent building was directed into the bioretention area, until a walkway was installed in July 2017 and this runoff was redirected onto the asphalt and towards Dry Well South 3. Although water was observed to pond and infiltrate in the practice after rain, water level was not measured within the underdrain where the HOBO was installed.

June 19, 2017

Practice	Designed Storage (ft^3)	Designed Drainage Area (ft^2)	# of storms recorded	# of storms w/ response
Bioretention South 1	194	1,373	28	0

Dimensions from engineering plans:
Bottom elevation: 177.10
Adjacent asphalt elevation: 178.3
8" UD
Overflow standpipe elev: 177.60
INV: 173.02
15 LF 8" HDPE UD at 0.5% to Dry Well S3

Bioretention South 1 Plantings

QTY	SYM	“BOTANICAL NAME COMMON NAME”	SIZE	ROOT	MIN. SPACING	REMARKS
TREES AND SHRUBS						
2	AC	“AMELANCHIER CANADENSIS SHADOWBUSH, SERVICEBERRY”	6’ HT	B&B	36” O.C.	
1	CO	“CEPHALANTHUS OCCIDENTALIS BUTTONBUSH”	1 GAL	CONT.	24” O.C.	MOUNDED
2	MY	“MYRICA PENSYLVANICA BAYBERRY”	1 GAL	CONT.	36” O.C.	AT LEAST ONE MALE & FEMALE REQ’D
1	VD	“VIBURIUM DENTATUM ARROWWOOD VIBURIUM”	36” HT	B&B	15’ O.C.	
PERENNIALS AND ORNAMENTAL GRASSES						
4	AG	“AGROSTIS ALBA REDTOP”	1 GAL.	CONT.	48” O.C.	CLUMP FORM
8	AS	“ANDROPOGON SCOPARIUS LITTLE BLUESTEM”	1 GAL	CONT.	24” O.C.	CLUMP FORM
10	CL	“CHASMANTHIUM LATIFOLIUM NORTHERN SEA OATS”	1 QT	CONT.	12” O.C.	CLUMP FORM
6	CV	“CAREX VULPINOIDEA FOX SEDGE”	1 QT	CONT.	12” O.C.	CLUMP FORM
100 SF	LO	“LOTUS CORNICULATUS BIRDFOOD DEERVETCH”	SEED		0.2 LB/1,000 SF	
8	PA	“PANICUM VIRGATUM SWITCHGRASS”	1 QT	CONT.	18” O.C.	CLUMP FORM
6	RF	“RUDBECKIA FULGIDA BLACK EYED SUSAN”	1 GAL	CONT.	12” O.C.	CLUMP FORM

Bioretention Area South 2

Linear bioretention area on the north edge of the South parking lot, between the lot and the sidewalk on North Front St. Although water was observed to pond in the practice after rain, water level was not measured within the underdrain where the HOBO was installed.

June 19, 2017

Practice	Designed Storage (ft^3)	Designed Drainage Area (ft^2)	# of storms recorded	# of storms w/ response
Bioretention South 2	575	2,549	28	0

Dimensions from engineering plans:
Bottom elevation: 176.60
Adjacent asphalt elevation: 177.5
Overflow standpipe elev: 177.10
INV: 173.02
40 LF 8" HDPE UD at 0.5% to Dry Well S 3

Bioretention South 2 Plantings

QTY	SYM	"BOTANICAL NAME COMMON NAME"	SIZE	ROOT	MIN. SPACING	REMARKS
TREES AND SHRUBS						
2	AC	"AMELANCHIER CANADENSIS SHADOWBUSH, SERVICEBERRY"	6' HT	B&B	36" O.C.	
1	CO	"CEPHALANTHUS OCCIDENTALIS BUTTONBUSH"	1 GAL	CONT.	24" O.C.	MOUNDED
2	MY	"MYRICA PENSYLVANICA BAYBERRY"	1 GAL	CONT.	36" O.C.	AT LEAST ONE MALE & FEMALE REQ'D
1	VD	"VIBURIUM DENTATUM ARROWWOOD VIBURIUM"	36" HT	B&B	15' O.C.	
PERENNIALS AND ORNAMENTAL GRASSES						
4	AG	"AGROSTIS ALBA REDTOP"	1 GAL.	CONT.	48" O.C.	CLUMP FORM
8	AS	"ANDROPOGON SCOPARIUS LITTLE BLUESTEM"	1 GAL	CONT.	24" O.C.	CLUMP FORM
14	CL	"CHASMANTHIUM LATIFOLIUM NORTHERN SEA OATS"	1 QT	CONT.	12" O.C.	CLUMP FORM
6	CV	"CAREX VULPINOIDEA FOX SEDGE"	1 QT	CONT.	12" O.C.	CLUMP FORM
100 SF	LO	"LOTUS CORNICULATUS BIRDFOOD DEERVETCH"	SEED		0.2 LB/1,000 SF	
8	PA	"PANICUM VIRGATUM SWITCHGRASS"	1 QT	CONT.	18" O.C.	CLUMP FORM
8	RF	"RUDBECKIA FULGIDA BLACK EYED SUSAN"	1 GAL	CONT.	12" O.C.	CLUMP FORM

Dry Well North 1

Dry well in the North parking lot driving lane, on the north side of the parking lot. Although the specific drainage area for this dry well was not calculated, it appears to be included within the drainage area for Permeable Pavers North 2, on the west side of the parking lot.

June 19, 2017

Practice	Designed Storage (ft^3)	Designed Drainage Area (ft^2)	# of storms recorded	# of storms w/ response
Dry Well North 1	2,116	Not calculated	28	2

	Min	Mean	Median	Max
Max water depth (ft)	0	0.008	0	0.188* (9/6/17)
Time to drain (hrs)	0.05	0.28	0.28	0.52**(9/6/17)

*Only 2 data points – 0.027 on 6/23/17 and 0.188 on 9/6/17
**Only 2 data points – 0.05 on 6/23/17 and 0.52 on 9/6/17

Dimensions from engineering plans:
8’ diameter
RIM = 176.9
INV 4” = 173.70 (from PPN1)
INV 8” = 173.00 (one section from BRN1, one section connects to DWN2)
SUMP = 167.23
Underdrain connects to DWN2 (same elevation, 173.00)

Drainage paths:
Included in Pervious Pavement North 2 drainage area, doesn’t have own drainage area
Total available storage = 2,116 cf

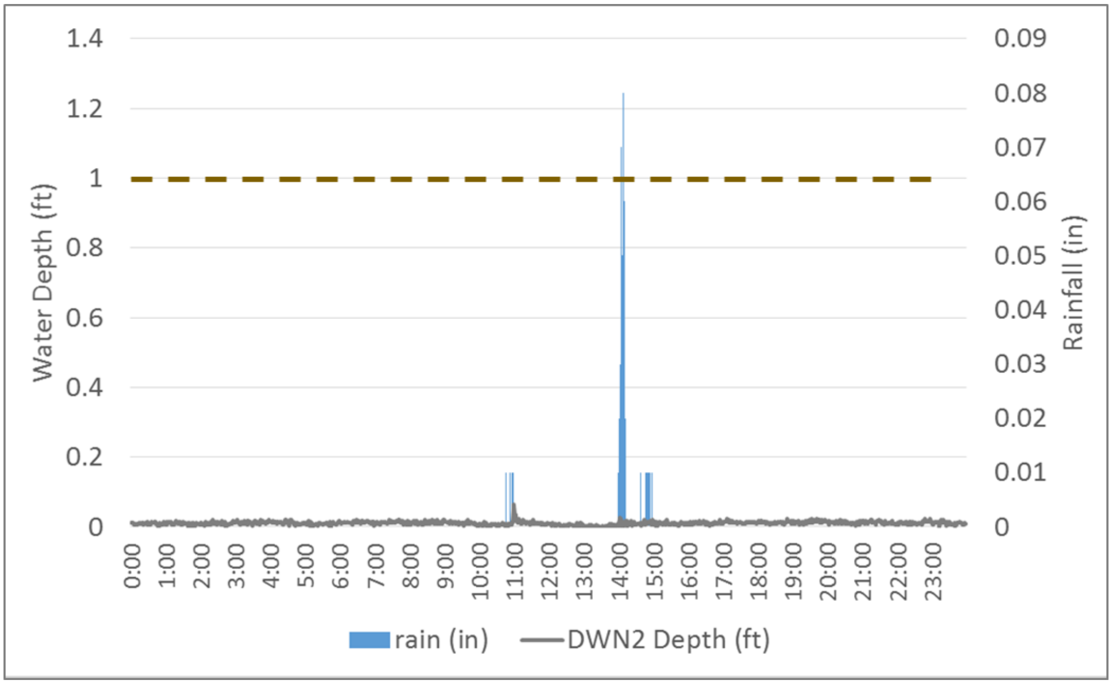
Dry Well North 2

Dry well in the north parking lot adjacent to parking spots, and partially within one parking spot. Although the specific drainage area for this dry well was not calculated, it appears to be included within the drainage area for Permeable Pavers North 2, on the west side of the parking lot. The PVC pipe housing within this dry well was clogged by leaf litter and other debris occasionally, and it appears as though the runoff would flow directly into the PVC pipe. As a result, the water levels measured may not be indicative of the water level within the rest of the dry well outside the pipe. During periods when the HOBO was stuck within the housing, certain storms were missed.

June 19, 2017

Practice	Designed Storage (ft^3)	Designed Drainage Area (ft^2)	# of storms recorded	# of storms w/ response
Dry Well North 2	2,096	Not calculated	25	20

	Min	Mean	Median	Max
Max water depth (ft)	0	0.132	0.056	0.499 (5/6/17)
Time to drain (hrs)	0.03	1.44	0.56	14.45 (9/7/17)



Example of water level in Dry Well North 2 during storm on August 4, 2017 (0.62 inches, most intense storm during study). The dashed line represents the gravel surface (HOBOs were buried 1 foot into the gravel), and water level above the line indicates ponding.

Dimensions from engineering plans:
8’ diameter
RIM = 176.9
INV 4” = 173.70 (from PPN2)
INV 8” = 173.00 (connects to DWN1)
SUMP = 167.23
Underdrain connects to DWN2 (same elevation, 173.00)

Drainage paths:
Included in PPN2, doesn’t have own drainage area
Total available storage = 2,096 cf

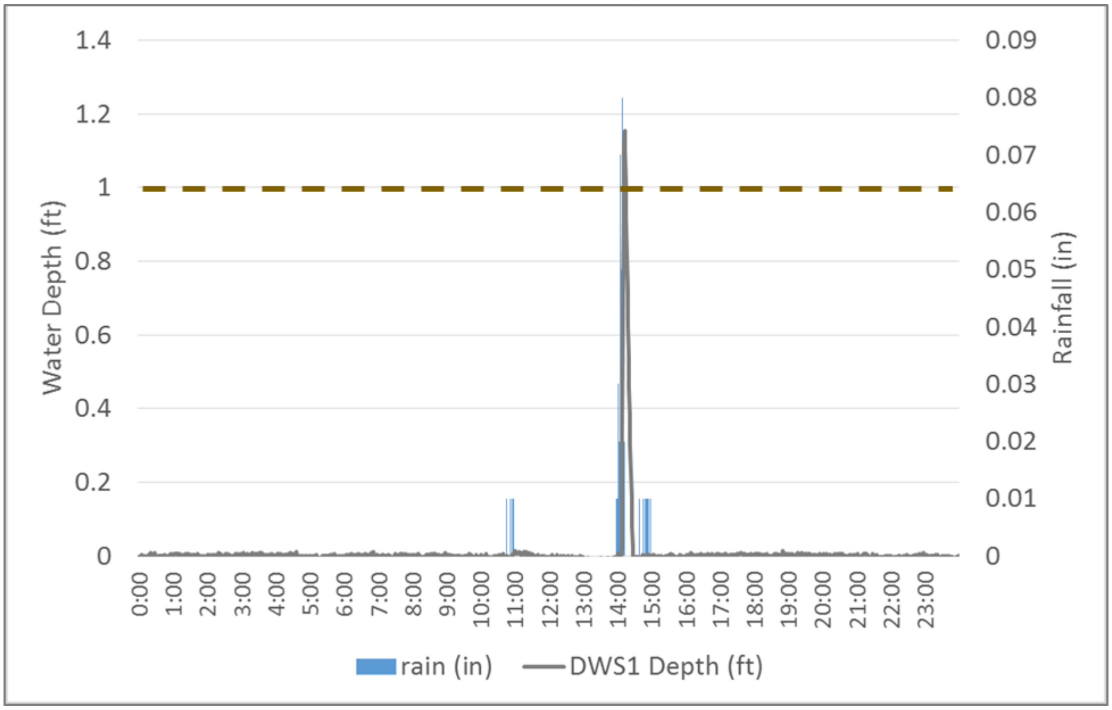
Dry Well South 1

Dry well in the South parking lot driving lane, on the west side of the parking lot. The original grading on this section of the parking lot resulted in the runoff to bypassing this dry well and flowing west out of the parking lot and into the storm drains on Green St. The grading was redone on May 20, 2017 to capture that runoff, and a much larger drainage area.

June 19, 2017

Practice	Designed Storage (ft^3)	Designed Drainage Area (ft^2)	# of storms recorded	# of storms w/ response
Dry Well South 1	1,541	11,277	28	12

	Min	Mean	Median	Max
Max water depth (ft)	0	0.269	0	2.834 (10/29/17)
Time to drain (hrs)	0.02	0.51	0.28	2.60 (10/29/17)



Example of water level in Dry Well South 1 during storm on August 4, 2017 (0.62 inches, most intense storm during study). The dashed line represents the gravel surface (HOBOs were buried 1 foot into the gravel), and water level above the line indicates ponding.

Dimensions from engineering plans:
8’ O.D. dry well
RIM = 176.65
INV 8” UD = 173.00
SUMP = 168.98
76 LF 8” HDPE UD at 0.5% to DWS2

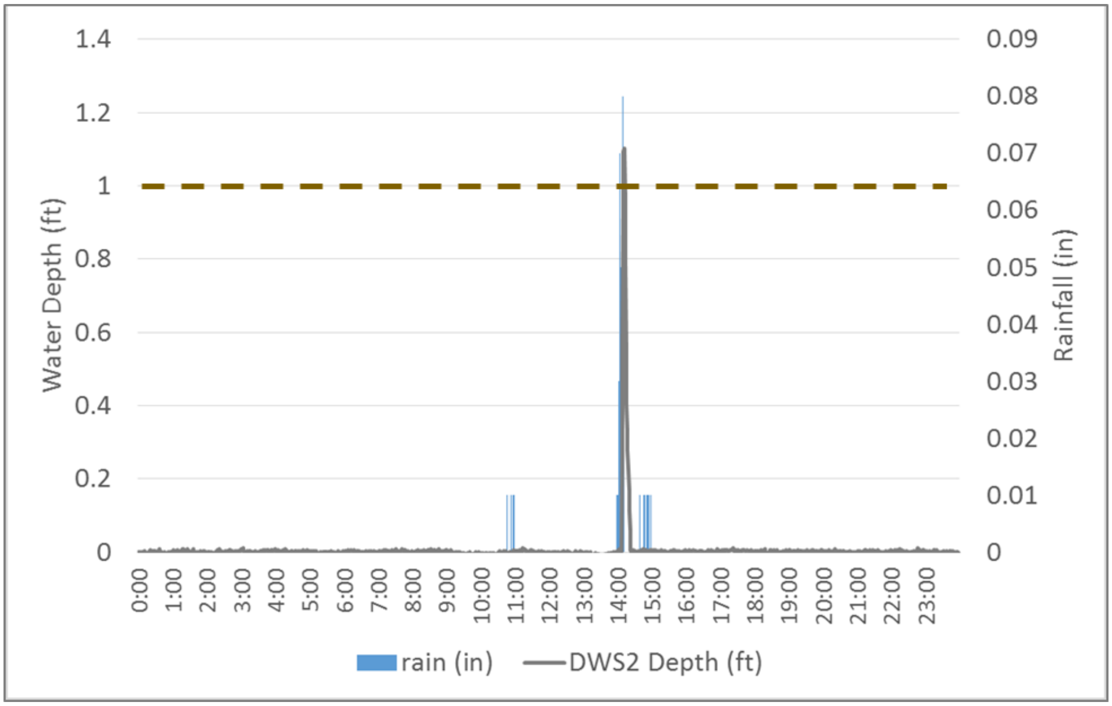
Dry Well South 2

Dry well in the South parking lot driving lane, in the center of the parking lot. The original location of the dry well and grading on this section resulted in a very steep slope surrounding the dry well. The dry well grate was raised 3.5 inches, and the area was re-graded on October 13, 2016.

June 19, 2017

Practice	Designed Storage (ft^3)	Designed Drainage Area (ft^2)	# of storms recorded	# of storms w/ response
Dry Well South 2	3,241	8,939	28	11

	Min	Mean	Median	Max
Max water depth (ft)	0	0.300	1.946	1.946 (10/29/17)
Time to drain (hrs)	0.02	0.42	0.20	2.37

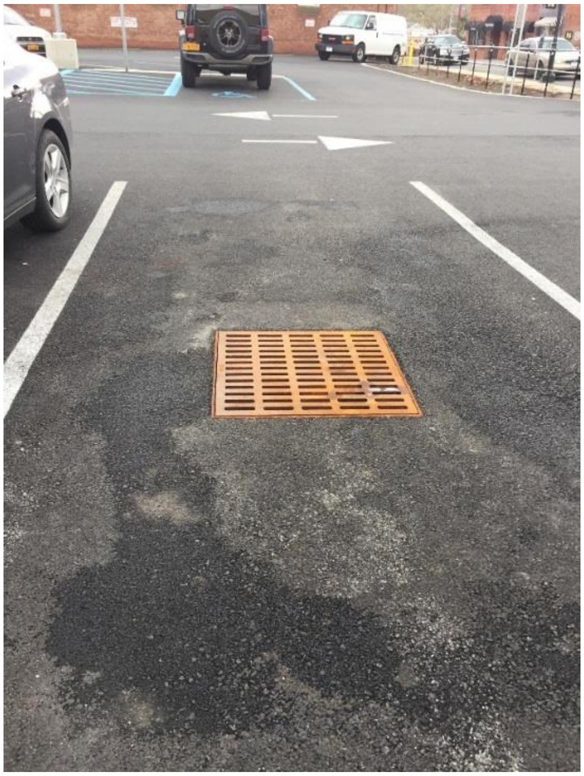


Example of water level in Dry Well South 2 during storm on August 4, 2017 (0.62 inches, most intense storm during study). The dashed line represents the gravel surface (HOBOs were buried 1 foot into the gravel), and water level above the line indicates ponding.

Dimensions from engineering plans:
8' O.D. Dry Well
RIM = 176.65
INV 4" = 173.00
INV 8" UD = 172.62
SUMP = 167.00

Dry Well South 3

Dry well in the South parking lot fully within a parking spot. This dry well was inaccessible most of the time, as there was almost always a car parked over it. In July 2017, the downspout carrying roof runoff from an adjacent building was redirected away from Bioretention Area South 1 and towards Dry Well South 3.



April 22, 2017

Practice	Designed Storage (ft^3)	Designed Drainage Area (ft^2)	# of storms recorded	# of storms w/ response
Dry Well South 3	1,263	1,295	5	3

	Min	Mean	Median	Max
Water Depth (ft)	0	0.025	0.025	0.075* (7/24/17)
Time to drain (hrs)	0.05	0.89	0.80	1.83** (7/24/17)

*Only 3 data points – 0.025 on 5/18/17, 0.025 on 7/18/17, and 0.075 on 7/24/17

**Only 3 data points – 0.05 on 5/18/17, 0.80 on 7/18/17, and 1.83 on 7/24/17

8’ O.D. Dry Well
RIM = 177.9
INV 4” = 173.30 (from pervious pavers)
INV 8” UD = 172.82 (from bioretention)
INV 8” UD = 172.95 (from bioretention)
SUMP = 169.23

APPENDIX F:
Green Infrastructure Maintenance and Design Recommendations for the City of Kingston

Recommendations for maintaining the existing green infrastructure in the Uptown municipal parking lots:

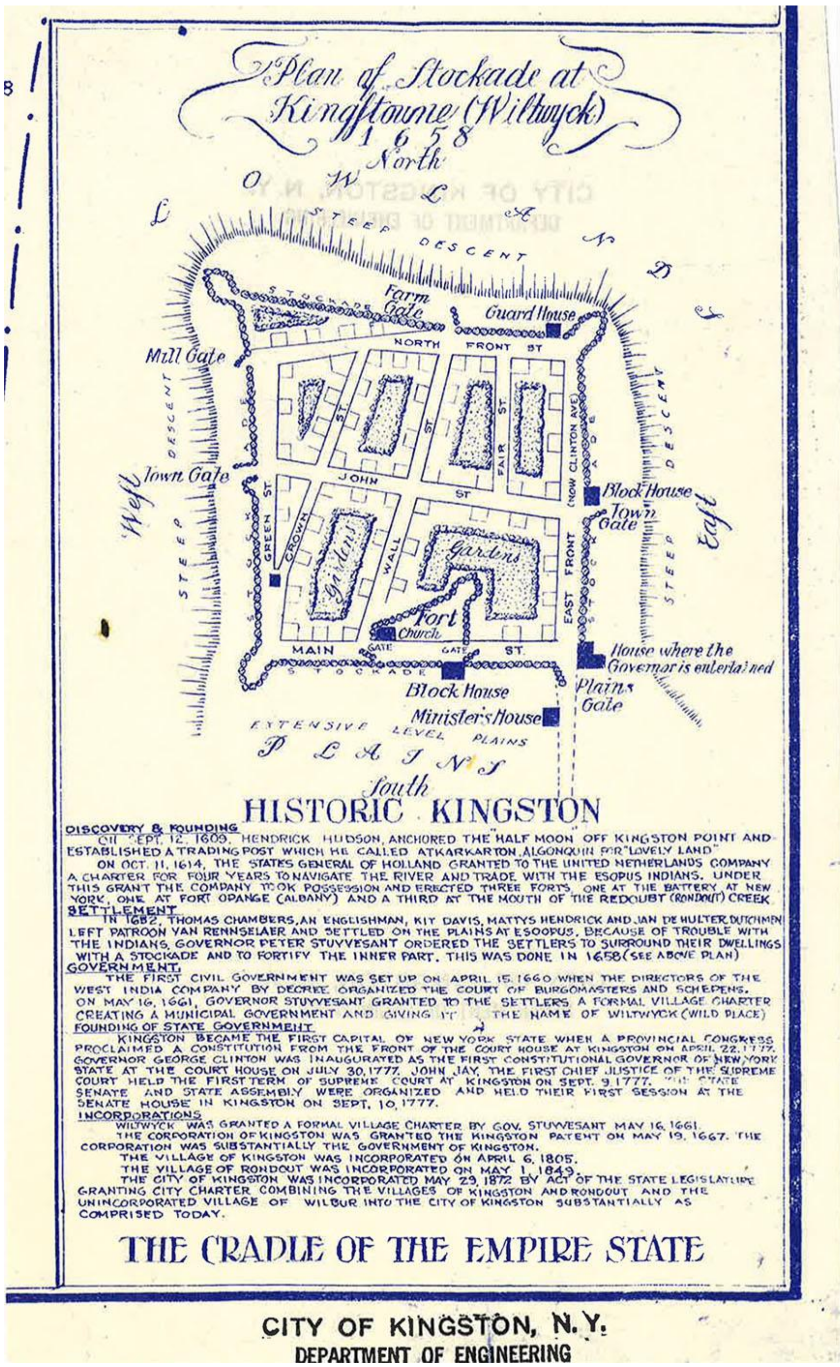
- Use mulch in all of the bioretention areas and rain gardens to reduce weed growth and hold moisture.
- Replace vegetation with denser native vegetation to improve aesthetics and reduce erosion. Consider using plants that can handle the weight of winter snow.
- Vacuum sections of pervious pavement to reduce clogging.
- Plant in the areas that are currently bare soil to reduce the amount of sediment that is mobilized, and make it clear to drivers that they should not be driving or parking in those areas.
- Add trash cans to reduce littering.
- Training for Department of Public Works maintenance staff.
- Consider educational signs to explain the role green infrastructure plays in these parking lots, especially since they are so visible.

Recommendations for designing future green infrastructure projects:

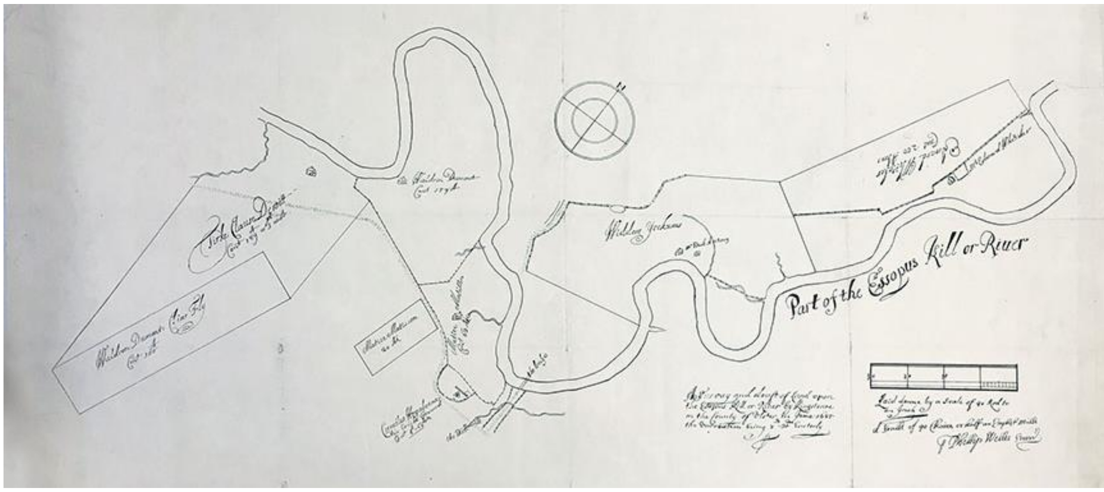
- Ensure that consulting engineers provide a maintenance plan, and that municipal staff have training to maintain them appropriately.
- Consider the size of drainage area for pervious pavers (and dry wells), and if it includes vegetation, how to limit clogging from debris.
- Make sure that green infrastructure sizing includes on-site stormwater conditions, including rooftop runoff that may be draining to the area.
- Consider trade-offs for maintenance of vegetated, surface-level practices versus maintenance of more hardscape features like dry wells and pervious pavers.
- Plan for pedestrians, and make sure it is clear where they can and should walk.
- Clearly mark entrances/exits in new parking lots.
- Planting plans that are easy to maintain and can handle the weight of snow.
- Steep side slopes may contribute to erosion within the practices; plan for a shallower grade.
- For vegetated practices, a forebay where runoff is directed into practices can help dissipate energy to reduce erosion, and also make maintenance easier in the future.

APPENDIX G:
Tracing the Tannery Brook Historic Materials

For additional materials and historic information, see Tracing the Tannery Brook: https://www.tracingtannerybrook.com/.

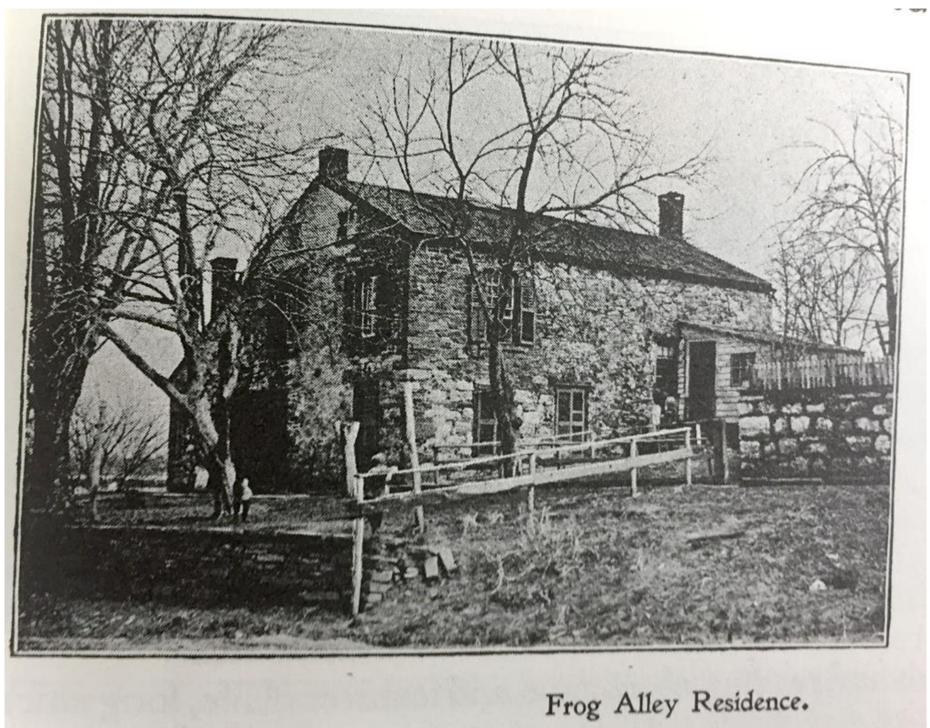


"Plan of Stockade at Kingstowne (Wiltwyck)." 1658. City of Kingston Engineering Department Archives. The Tannery Brook and mill were just outside the Mill Gate, in the northwest corner of the Stockade.

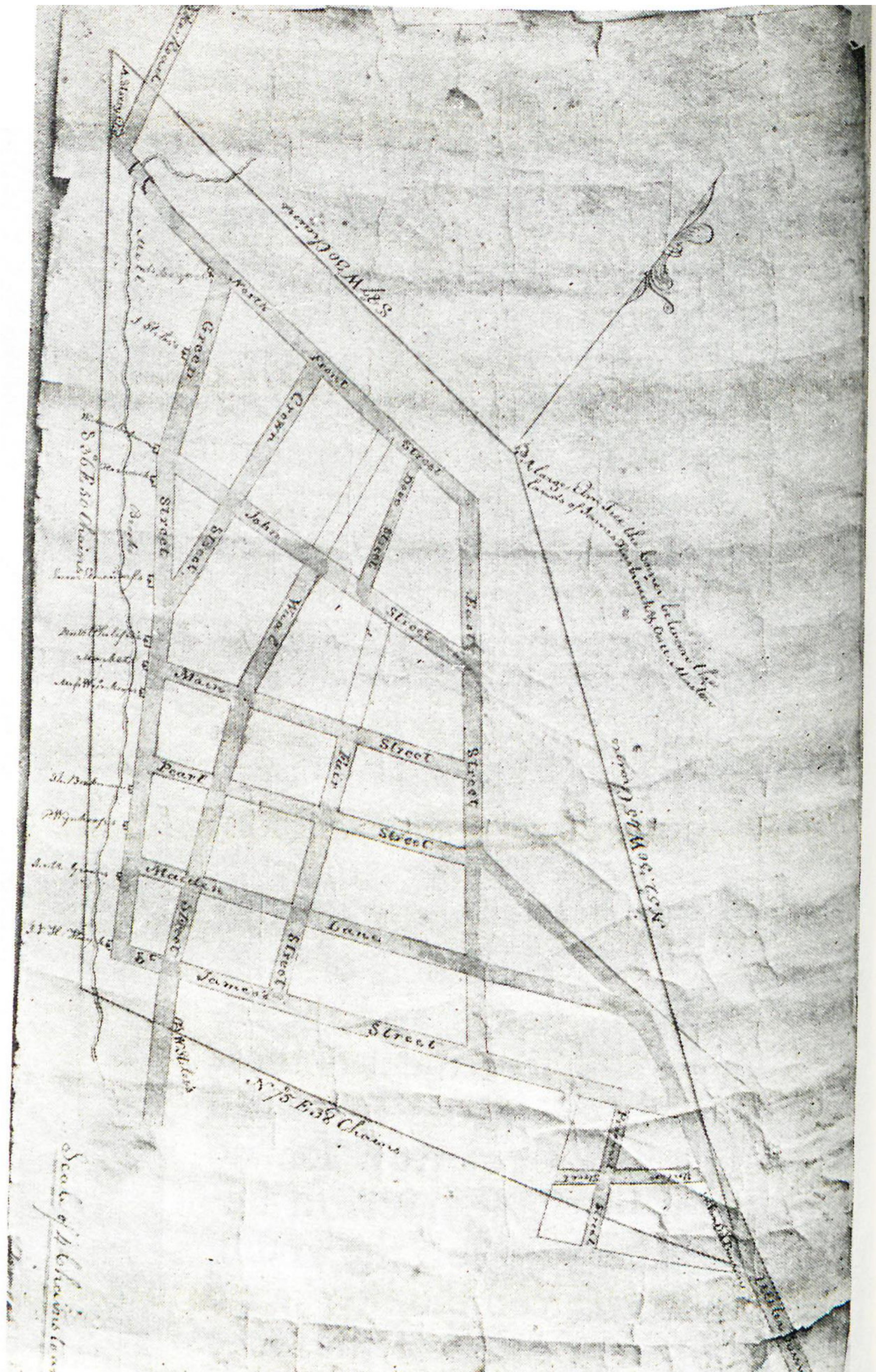


"Map, Part of the Esopus Kill & Lands near Kingston, NY." 1685. Phillip Welles Swon. Senate House State Historic Site, Kingston, NY, Office of Parks, Recreation and Historic Preservation. SH.1987.20. This map includes the earliest known map of the Tannery Brook, along with the mill and Hoogeboom's brickyard.

"Painting of 1695 Kingston." 2015. L.F. Tantillo. Senate House State Historic Site, Kingston, NY, Office of Parks, Recreation and Historic Preservation. The Tannery Brook and mill pond are in the foreground.

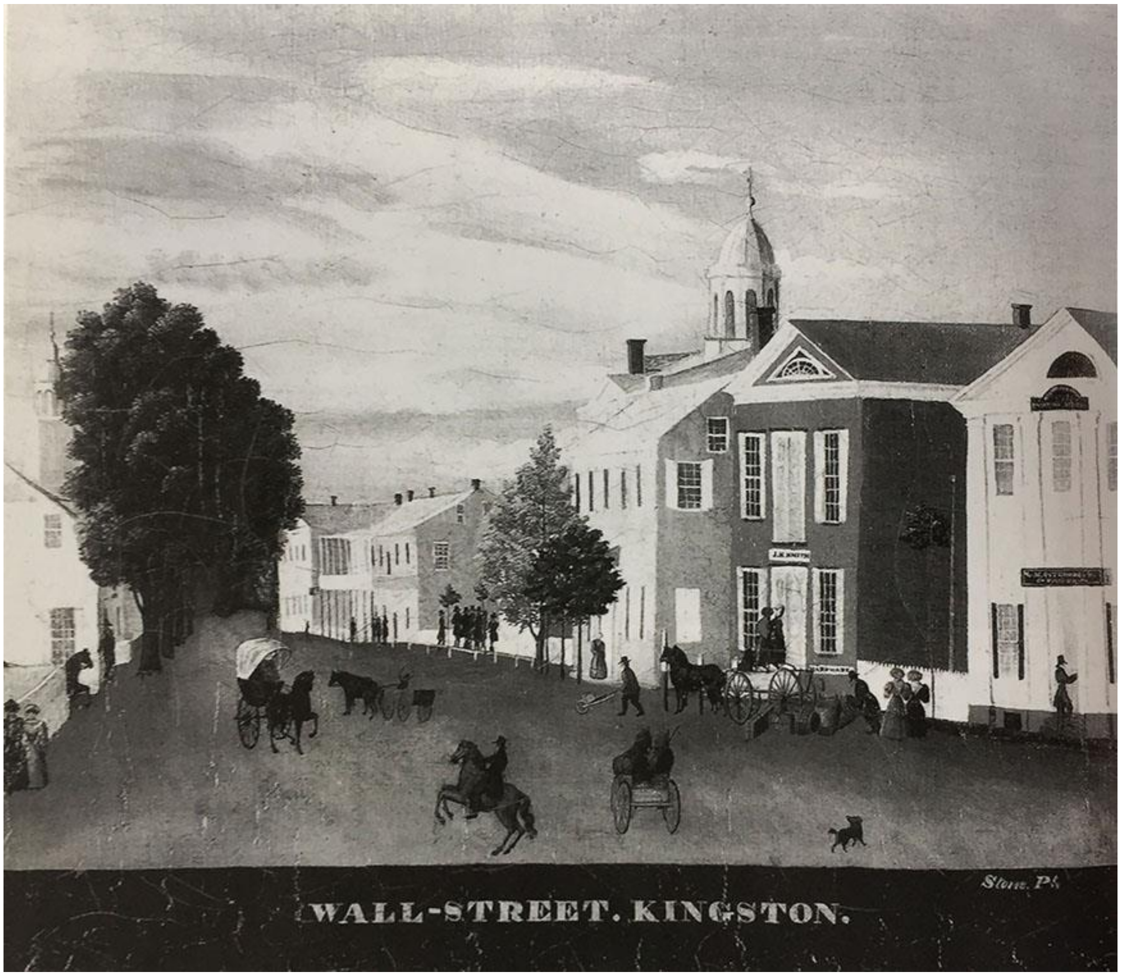


Louw Bogardus Ruins, 2018 (top). Frog Alley Residence. 1896. *Picturesque Ulster* by Richard Lionel de Lisser (bottom). This was the mill house for the mill on the Tannery Brook, and may have been built as early as 1661.



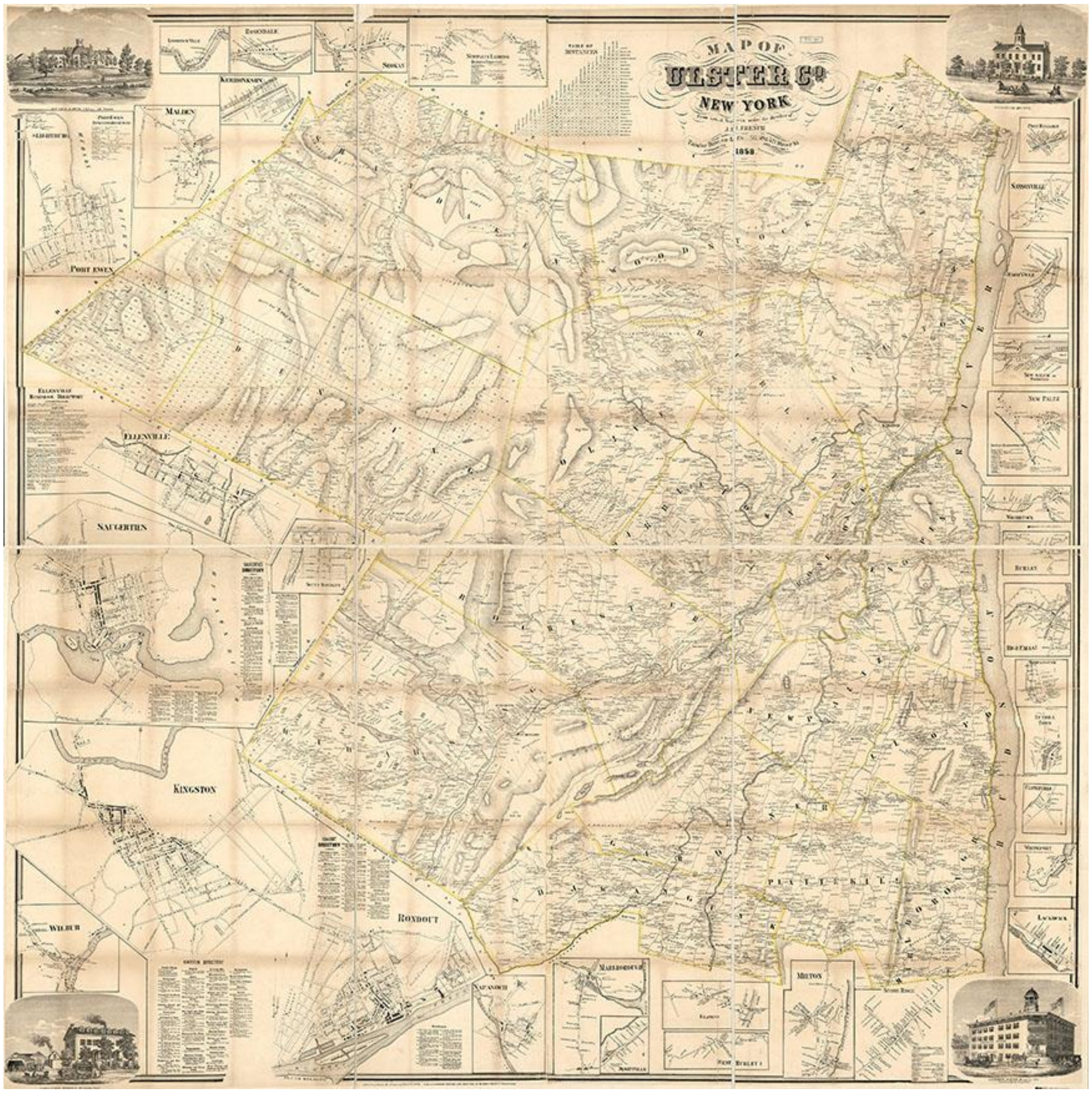
Ye Olde Kingston.

“Ye Olde Kingston.” 1896. Picturesque Ulster by Richard Lionel de Lisser. This map includes the Tannery Brook, to the west of the stockade area. Although this map is not dated, it is likely around 1820, before Wall Street was extended and after the mill pond was drained. There is still a bridge at North Front Street, but no other roads cross the brook. The stream is labeled “Mill Brook.”

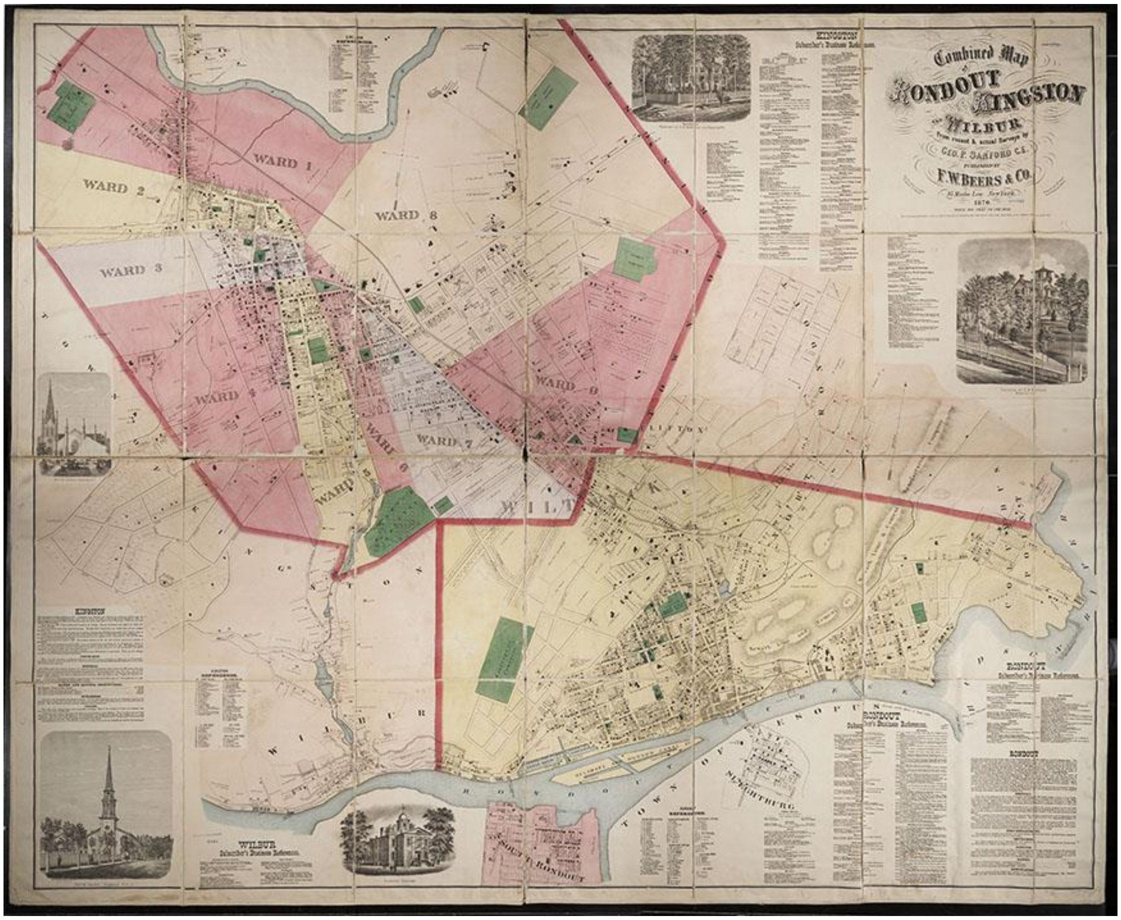


“Wall-Street. Kingston.” 1832. From *Images of America: Kingston* by Edwin Millard Ford. In the early 1800s, Wall Street and North Front Street established themselves as the commercial center of Kingston.

“View of Kingston.” 1819. John Vanderlyn. Senate House State Historic Site, Kingston, NY, Office of Parks, Recreation and Historic Preservation. SH.1975.598. This watercolor is a view approximately from the south end of Wall Street, looking over the agricultural fields within the Tannery Brook’s watershed, toward the Village of Kingston and Catskill Mountains.

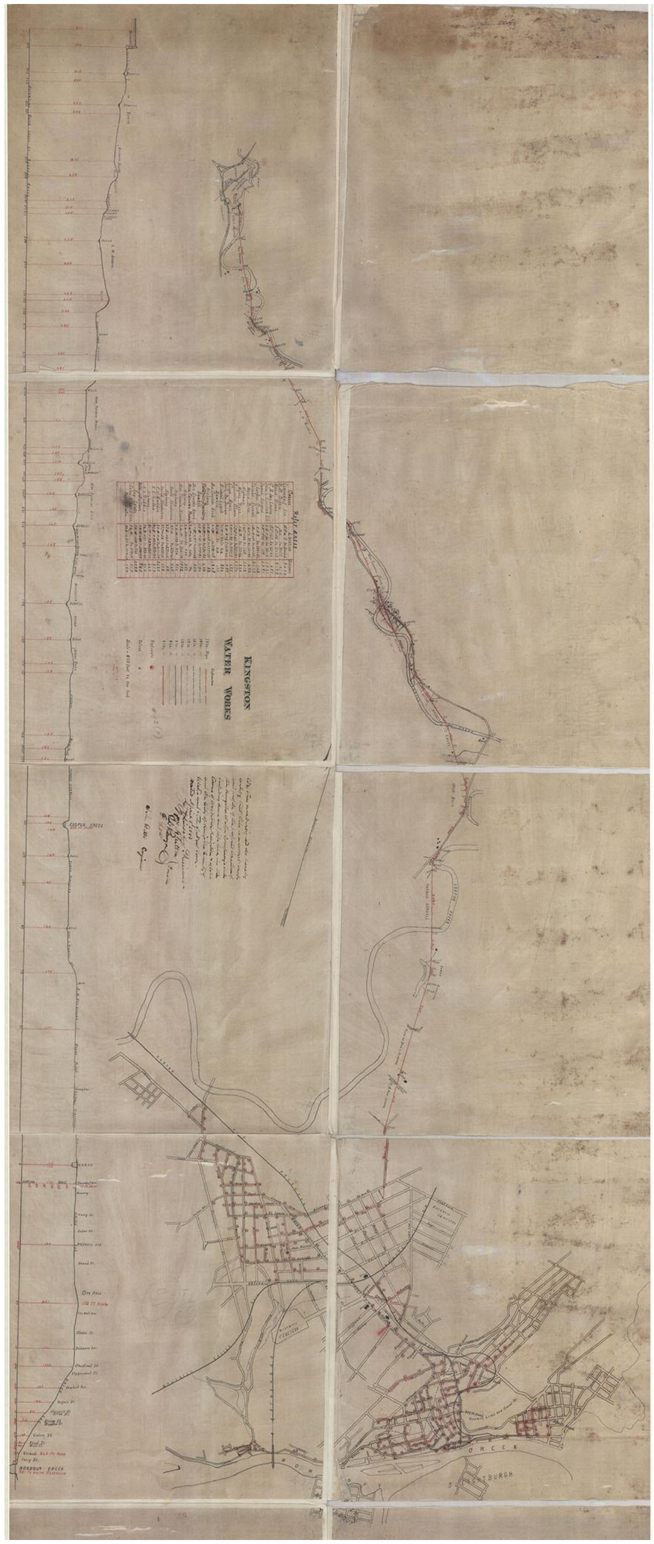


“Map of Ulster County, New York: from actual surveys.” 1858. J.H. French; Taintor, Dawson, & Co. Library of Congress, Geography and Map Division. According to Blumin (1976), the earliest map of Kingston roads and buildings was likely the 1854 Ulster County map; this map from 1858 includes an inset map of Kingston roads, buildings, and directory of businesses.

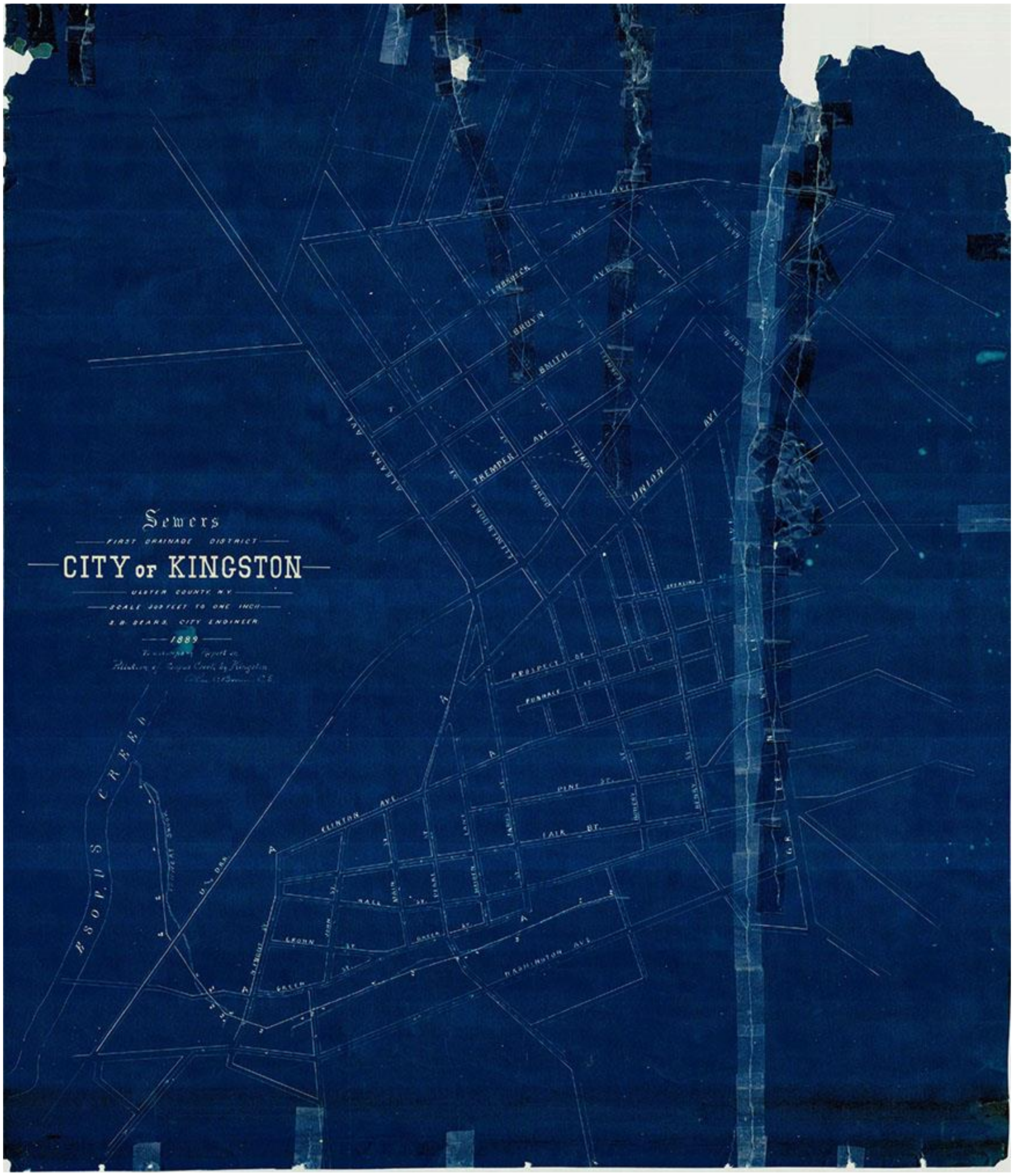


"Combined Map of Rondout, Kingston, & Wilbur." 1870. Geo. P. Sanford; F.W. Beers & Co. Friends of Historic Kingston. This detailed map includes the Tannery Brook, along with locations of farms, orchards, a tannery, and other businesses.

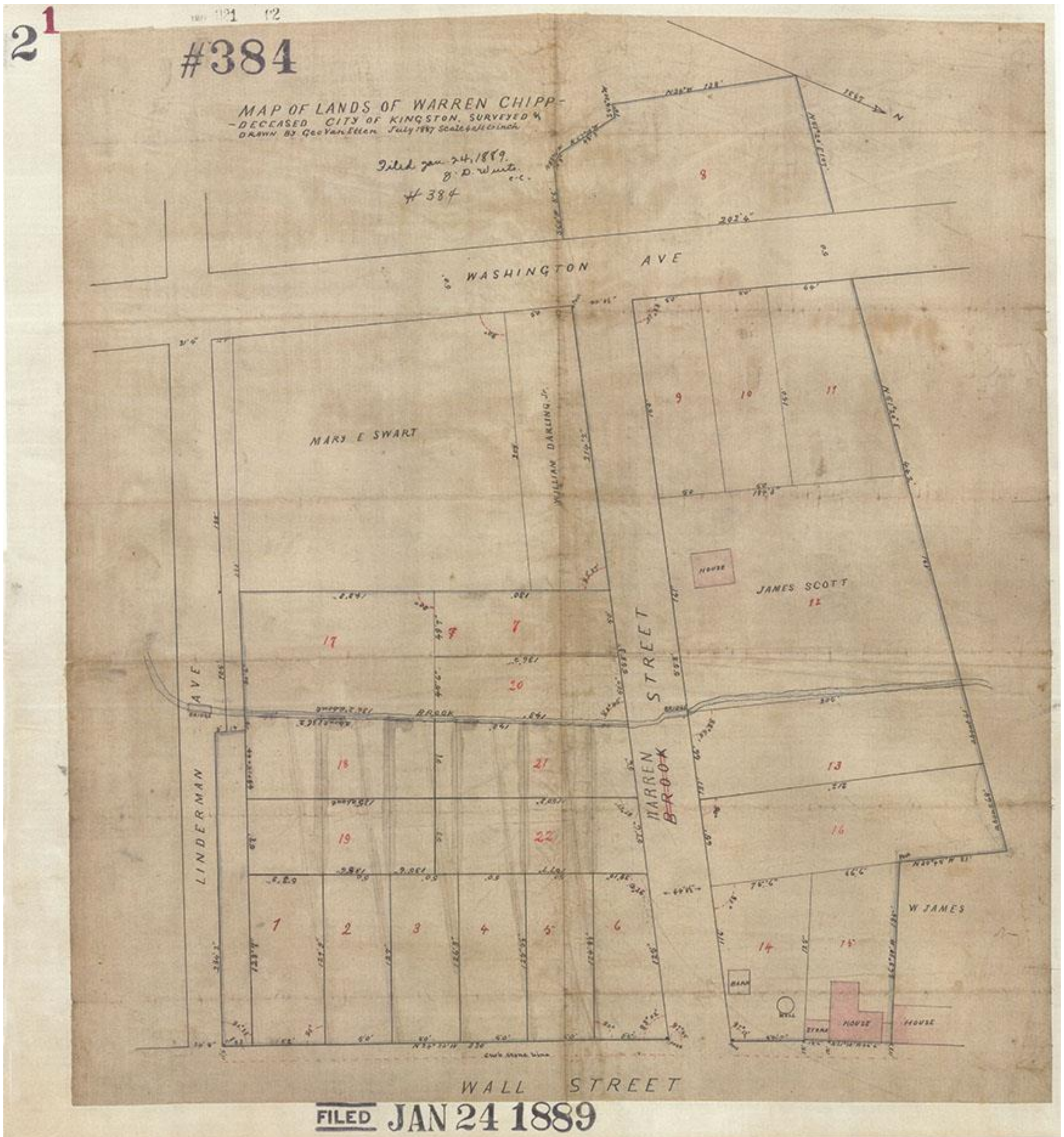
Carter’s Pond. Circa 1890. Friends of Historic Kingston. A dam on the Tannery Brook created Carter’s Pond, which extended from Lucas Avenue toward Main Street, between Green Street and Lucas Avenue. It was well-known as an excellent ice-skating site.



“Kingston Water Works.” 1883. Kingston Water Company. Ulster County Archives. This map showed how drinking water traveled from the Saw Kill in Woodstock to homes and businesses in Kingston, including a profile of the properties through which the system passed.

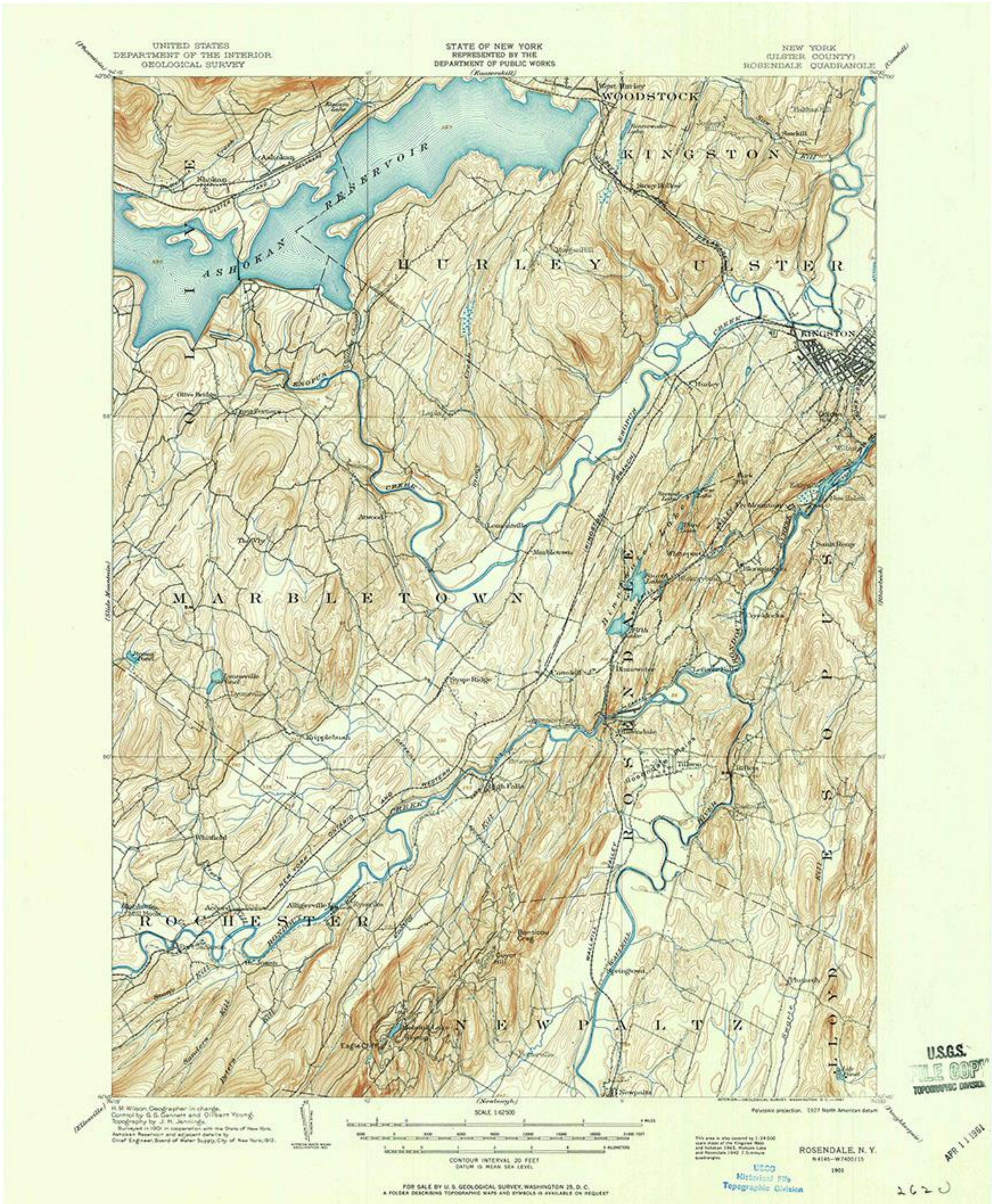


“Sewers First Drainage District City of Kingston.” 1889. S.B. Sears. City of Kingston Engineering Department Archives. These were the first sewers installed in Uptown Kingston, and included a trunk line along the Tannery Brook to discharge into the Esopus Creek.

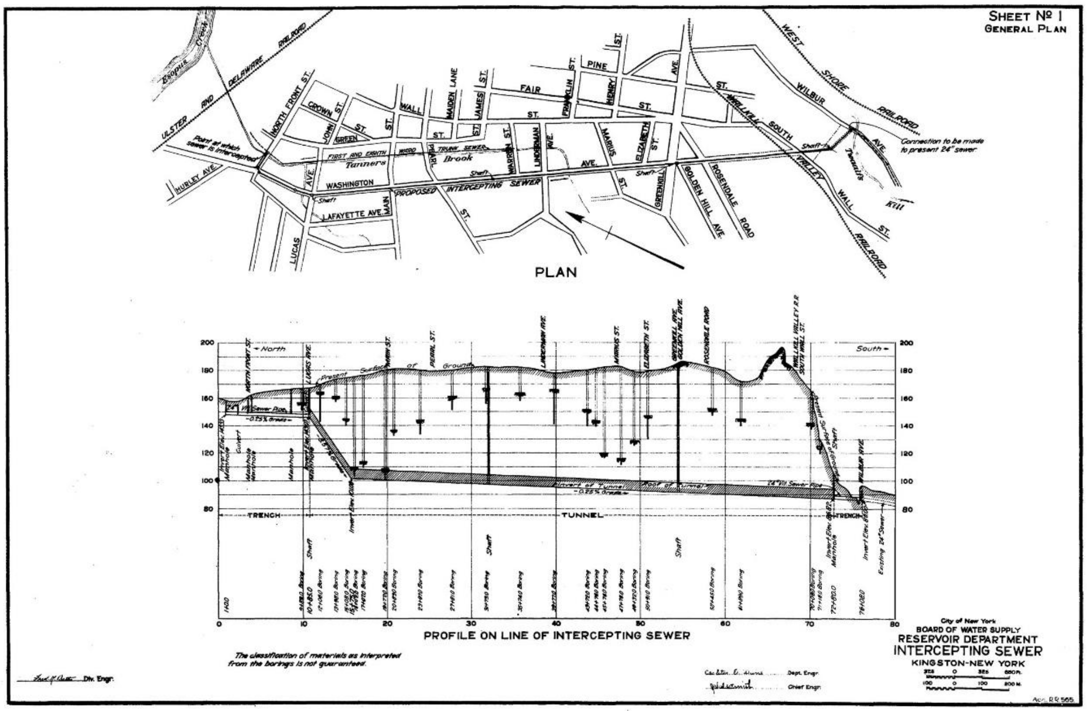


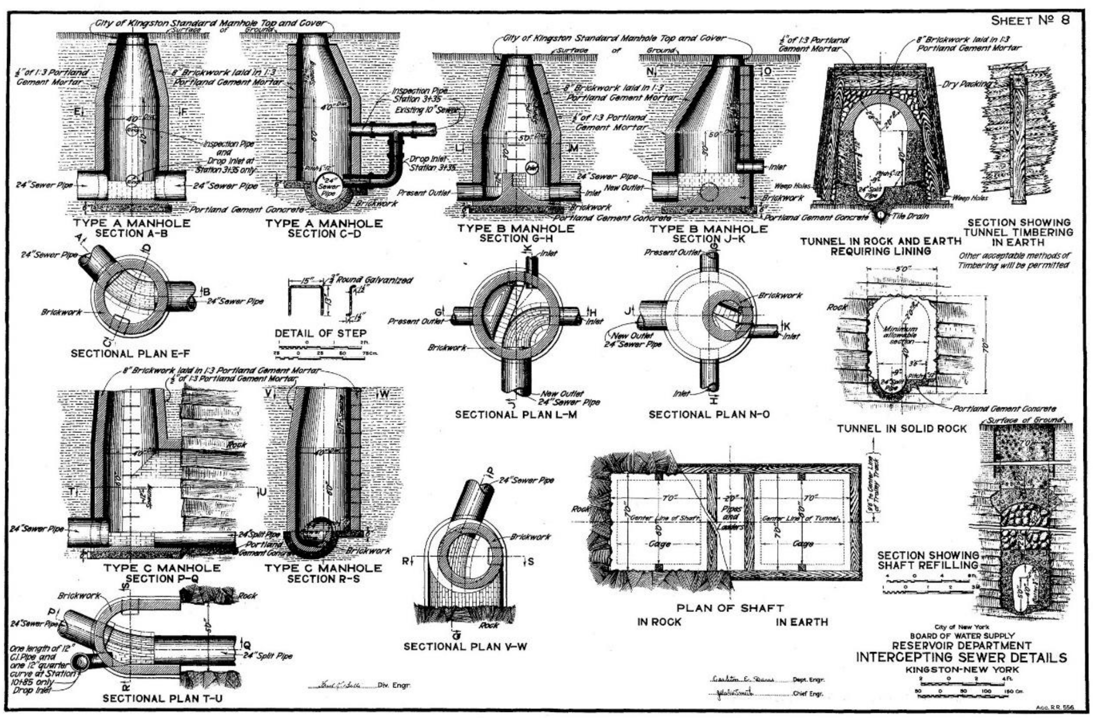
"Map of Lands of Warren Chipp." 1887. Geo. Van Etten. Ulster County Archives. This map shows the subdivision of larger agricultural properties into smaller lots for housing. It also shows the change in name from "Brook Street," which crossed the Tannery Brook, to "Warren Street."

"Map Showing Property Owned by Crosby Kelly in the City of Kingston, Ulster County, NY." 1895. Ulster County Archives. This map shows the subdivision of property for residential development, including the channelization of the Main Street Brook between Emerson Avenue and Lafayette Avenue.



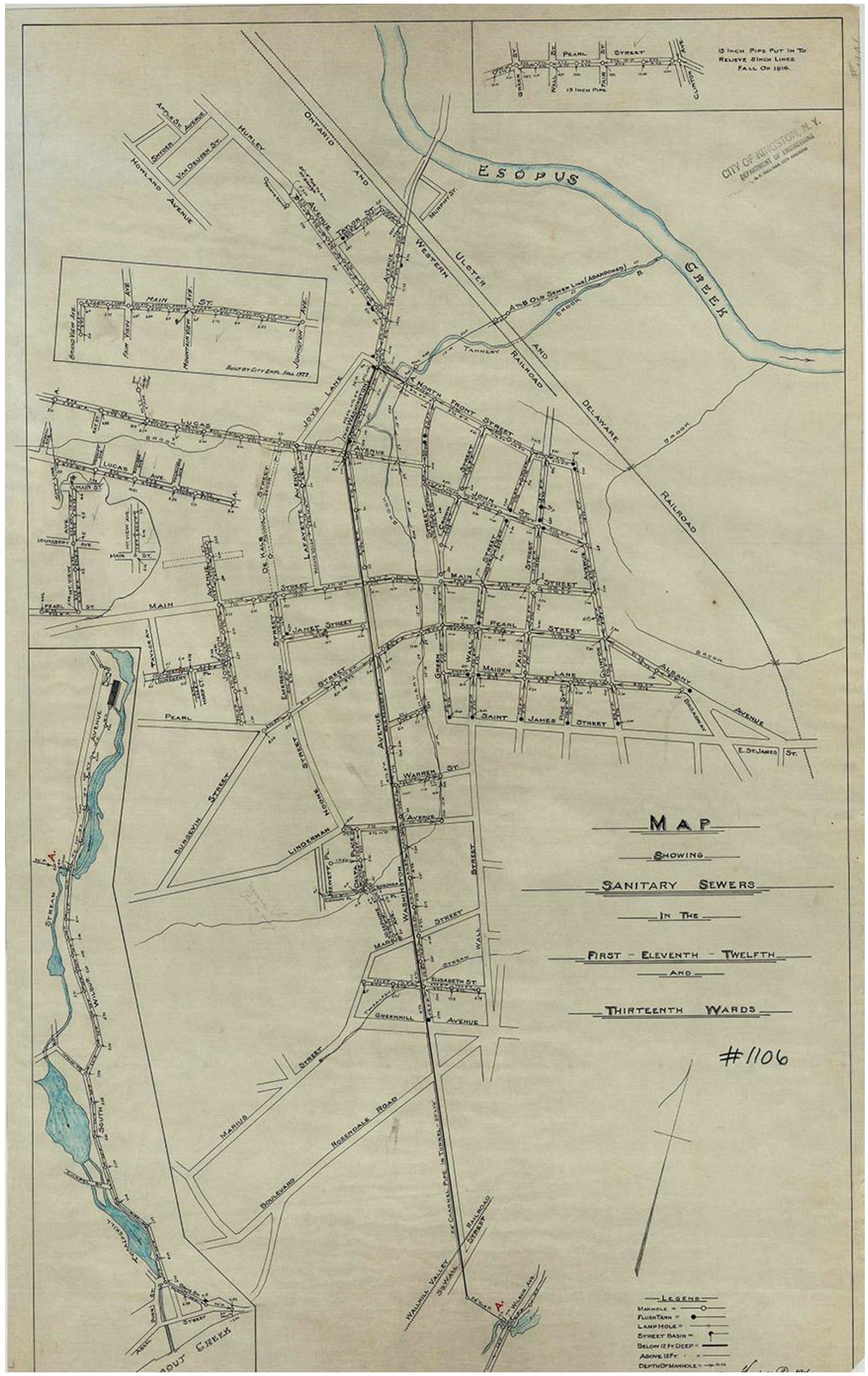
"New York (Ulster County) Rosendale Quadrangle." 1901. United States Geological Survey. This map includes the Ashokan Reservoir; the construction of this reservoir had a major impact on the Esopus Creek and then the Tannery Brook. The map also shows the Tannery Brook, which is surprising for such a small stream at this scale.



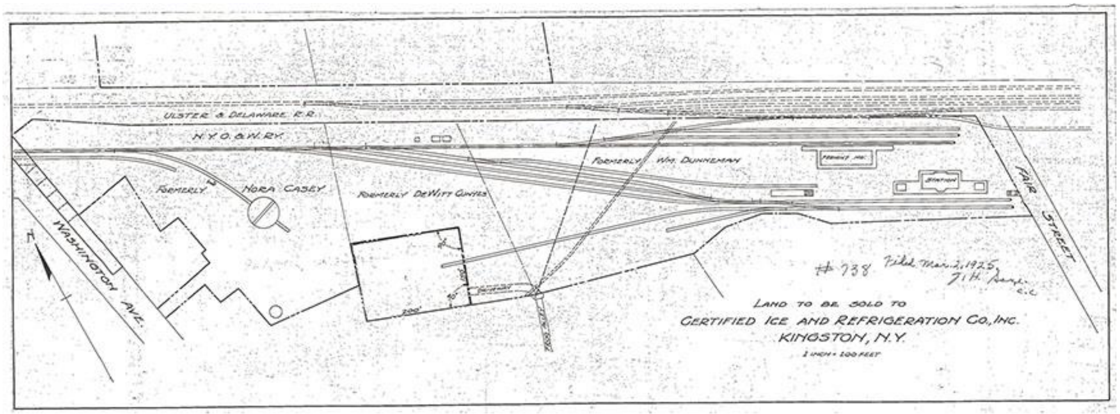


"Intercepting Sewer & Intercepting Sewer Details." 1909. New York City Board of Water Supply. City of Kingston Engineering Department Archives. This intercepting sewer carried sanitary sewage away from the Esopus Creek and into the Twaalfskill and Rondout Creek. Eventually, storm sewers were added to the tunnel, and the Tannery Brook itself was added via the Tannery Brook shaft at Linderman Avenue.

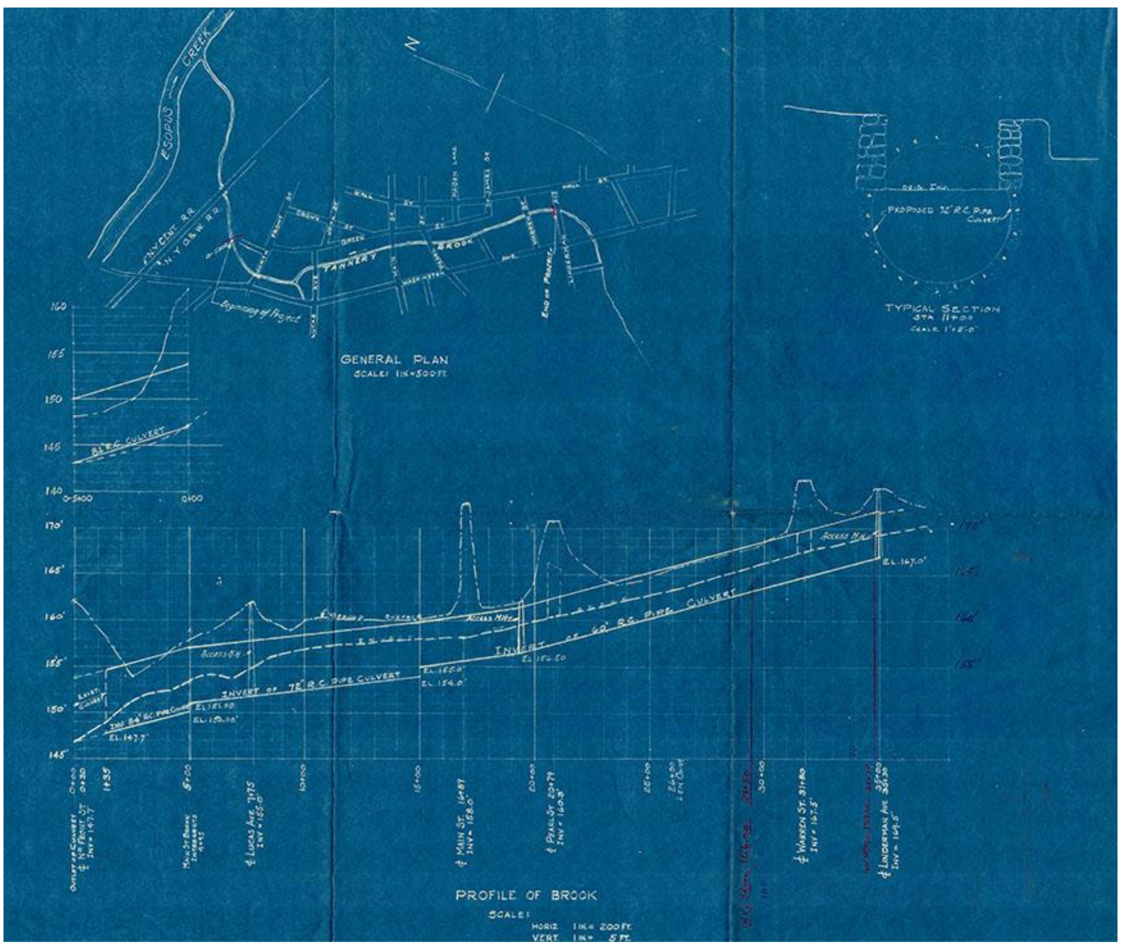
“Map Showing Storm Water Sewers in the First - Eleventh - Twelfth and Thirteenth Wards.” 1916. Edward B. Codwise. City of Kingston Engineering Department Archives. This map shows the connections of the storm sewer system to the Tannery Brook.



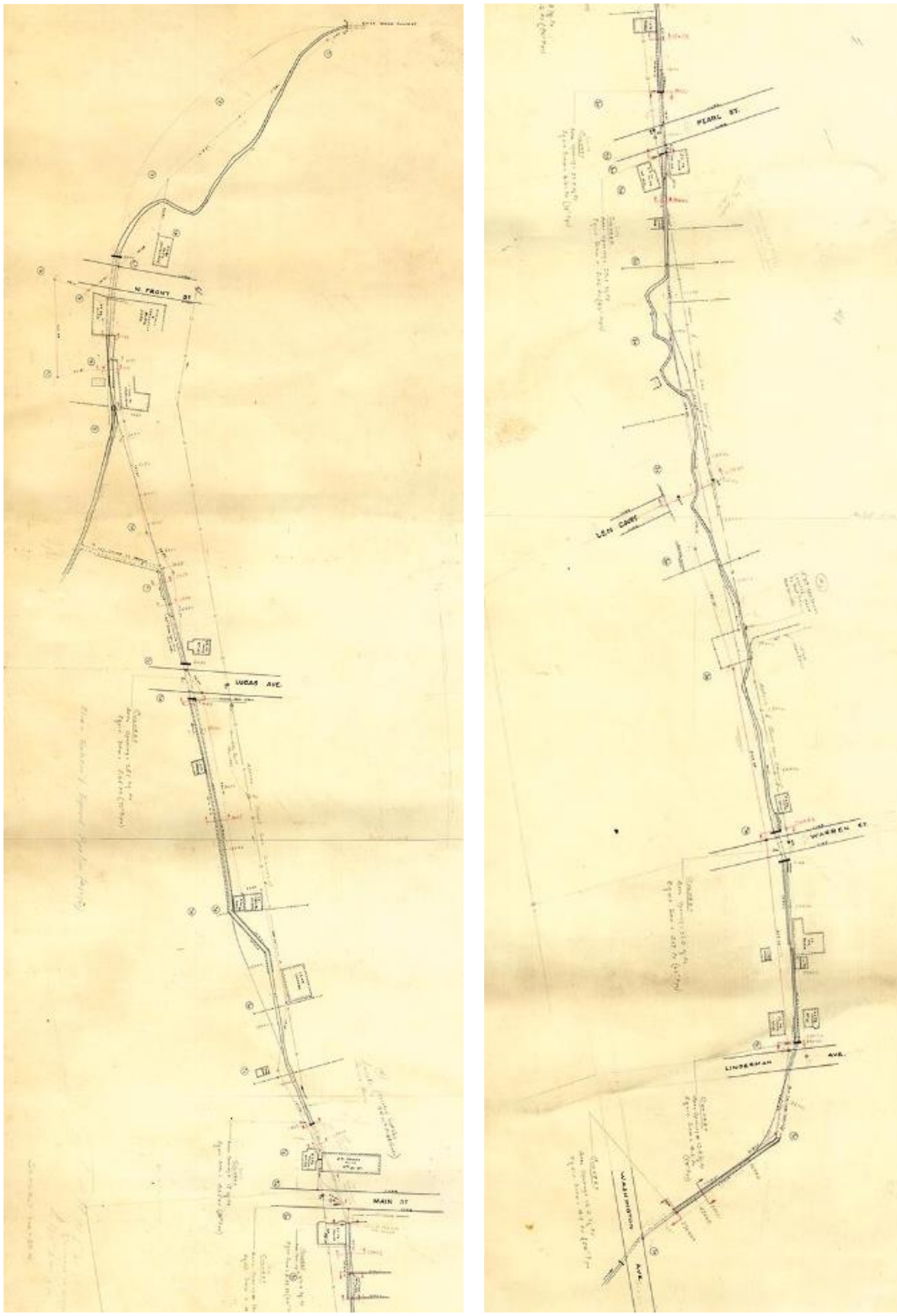
"Map Showing Sanitary Sewers in the First - Eleventh - Twelfth and Thirteenth Wards." 1916. Edward B. Codwise. City of Kingston Engineering Department Archives. This map shows the sanitary sewers in Uptown Kingston, including the old line that carried sewage to the Esopus Creek, and the new tunnel below Washington Avenue that carried sewage to the Twaalfskill and the Rondout Creek.



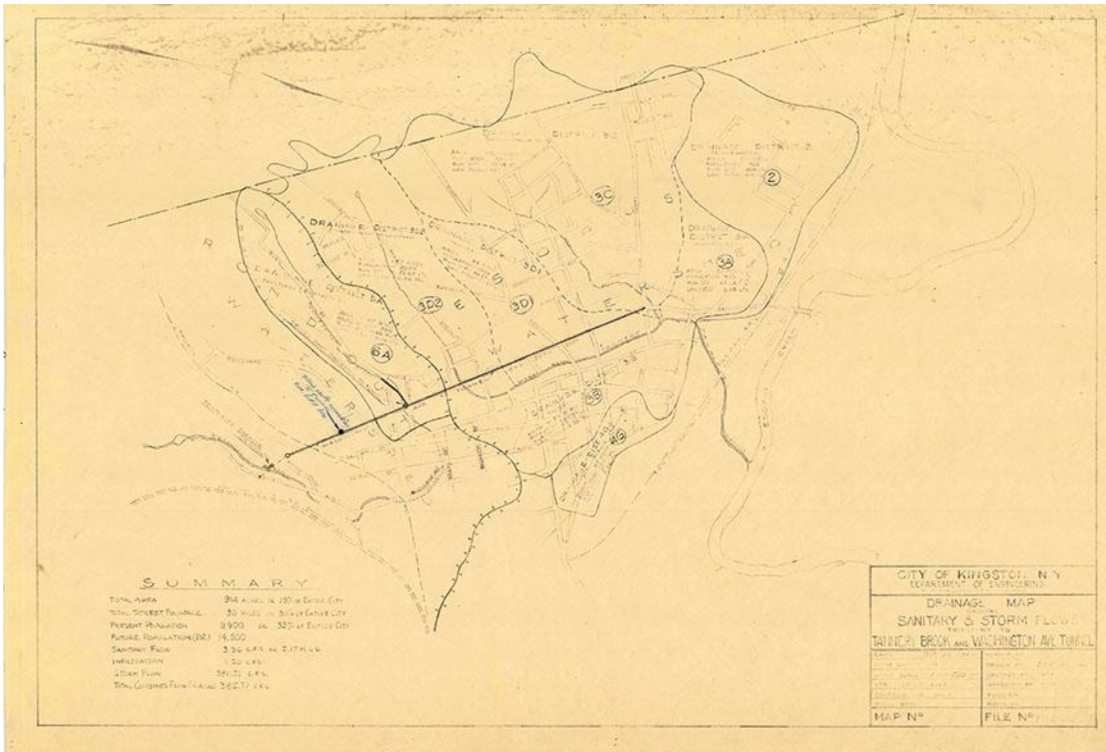
"Land To Be Sold to Certified Ice and Refrigeration Co, Inc. Kingston, NY." 1925. Ulster County Archives. The dashed line under the railroad tracks (coming from Frog Alley) is the Tannery Brook.



"Tannery Brook - Storm Water Drain." 1946. NYS Post War Public Works Planning Commission. City of Kingston Engineering Department Archives. This map shows plans to bury the Tannery Brook in a culvert from Frog Alley to Linderman Avenue. Similar plans were created to bury the Main Street Brook at the same time.

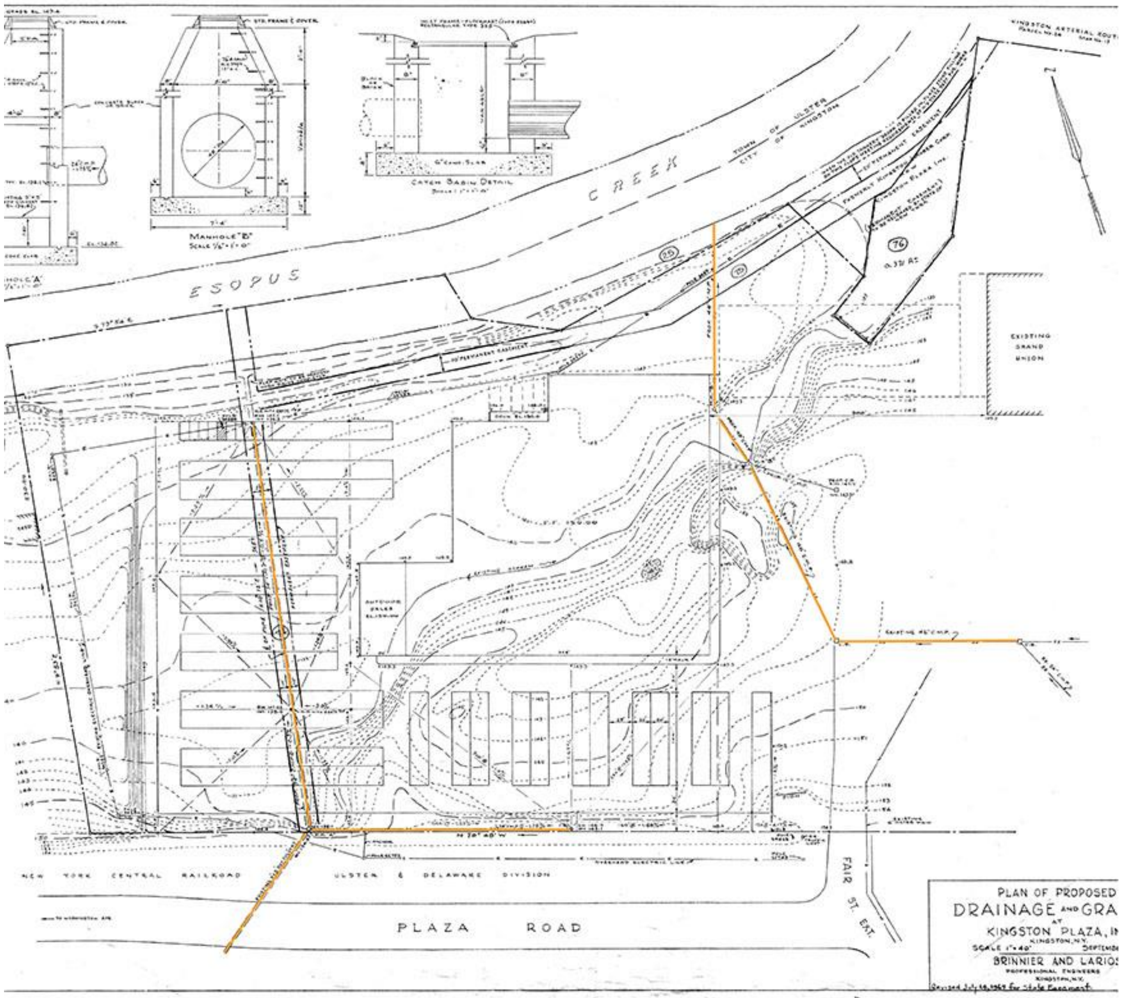


“Tannery Brook Location Survey (Converse St Culvert to Washington Ave).” 1947. City of Kingston Engineering Department Archives. This detailed survey includes the size of culverts and location of walls (north portion, left, and south portion, right). It also shows that a portion of the brook had been buried between Lucas Avenue and North Front Street, and another section was buried north of North Front Street.

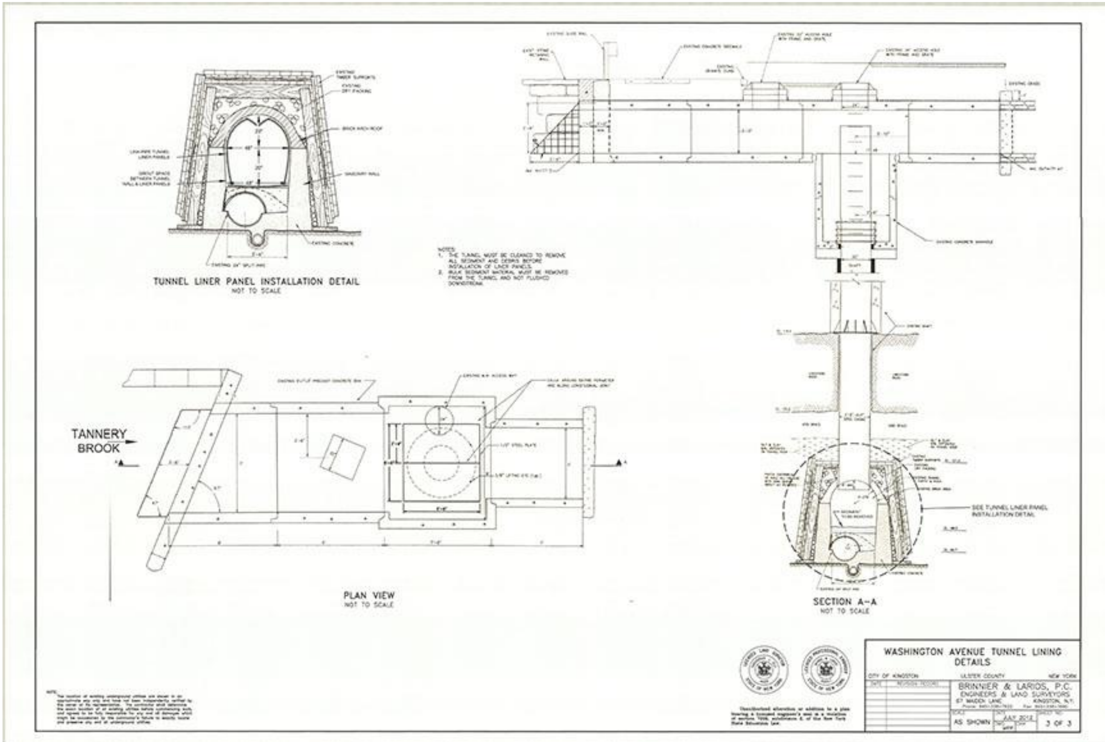


"Drainage Map Showing Sanitary and Storm Flows Tributary to the Tannery Brook and Washington Avenue Tunnel." 1949. City of Kingston Department of Engineering. City of Kingston Engineering Department Archives. This map shows the subwatersheds of the Tannery Brook, their estimated sanitary and storm sewer flows, and the Washington Avenue tunnel that carried water to the Twaalfskill. This is the earliest known map of the Tannery Brook that includes its watershed.

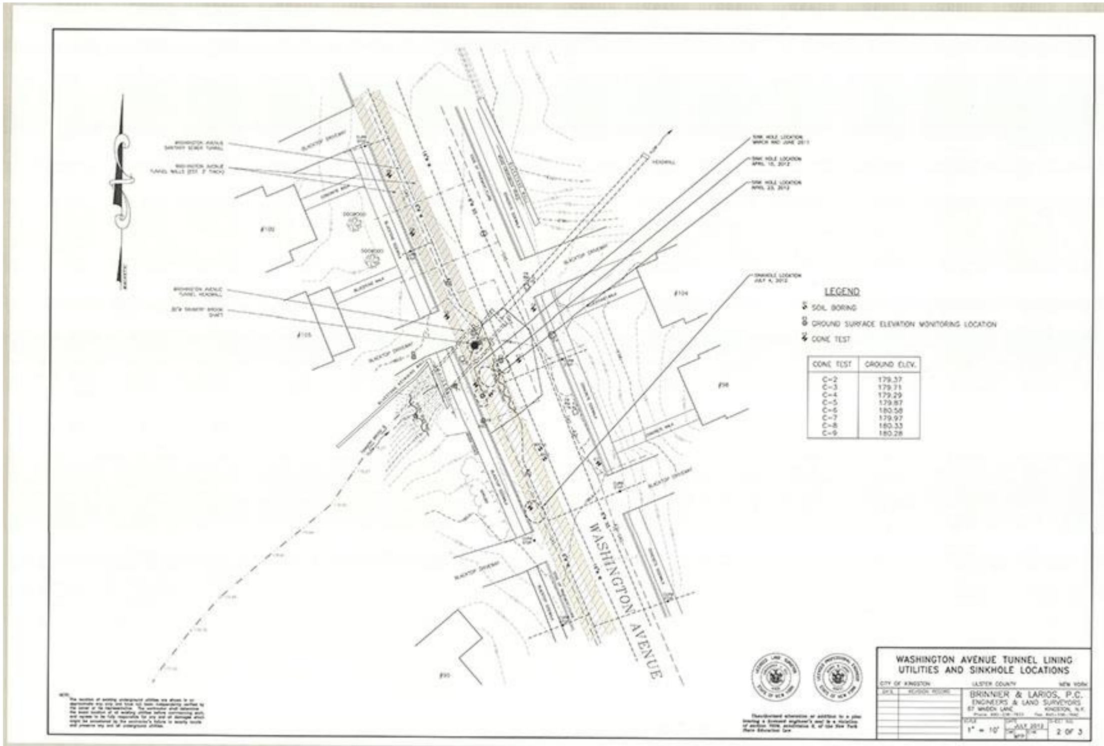
“North Front Street Looking West from Wall Street, North Side.” 1960s. Friends of Historic Kingston, Charles Niles Collection. While Wall Street and North Front Street were important business districts, they were increasingly threatened by suburban development outside the City of Kingston.



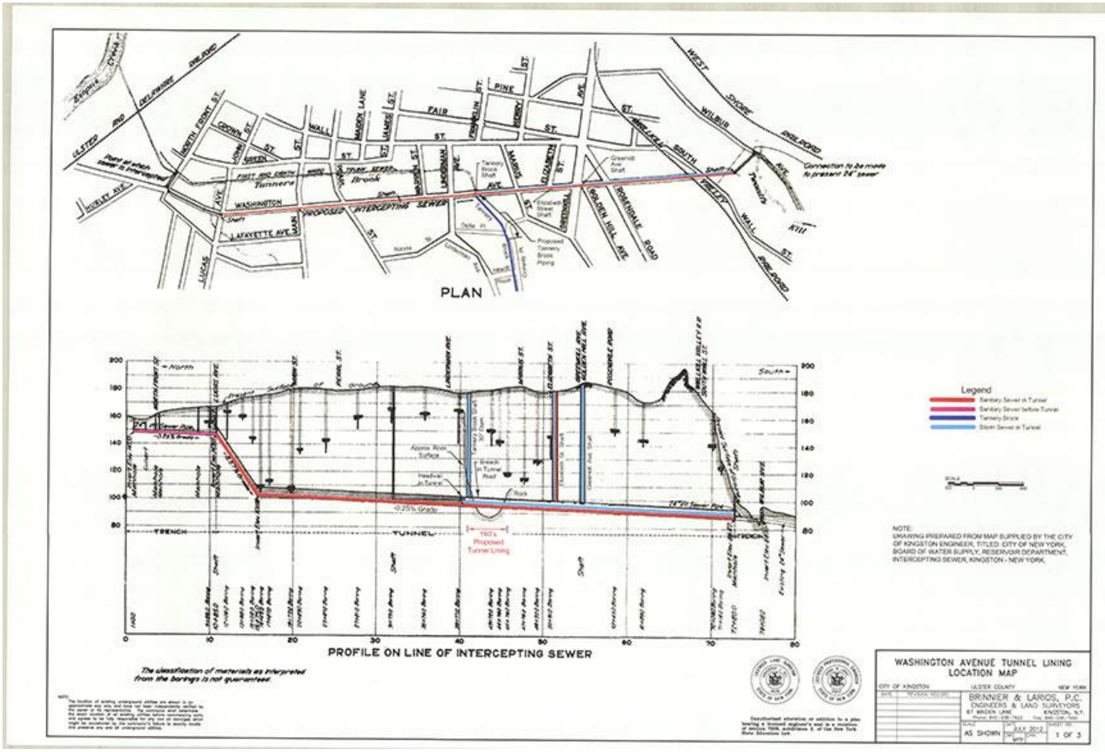
"Plan of Proposed Drainage and Grading at Kingston Plaza." 1969. Brinnier & Larios. City of Kingston Engineering Department Archives. The Tannery Brook is included within the storm sewer indicated by the yellow line on the left. Topographic lines on the base map indicate its former course through the lowlands.



"Washington Avenue Tunnel Lining Details." 2012. Brinnier & Larios. Ulster County Department of the Environment. This drawing dispays how the void space around the Tannery Brook shaft caused the road to collapse.



“Washington Avenue Tunnel Lining Utilities and Sinkhole Locations.” 2012. Brinnier & Larios. Ulster County Department of the Environment. This map shows the location of the sink hole, adjacent to the Tannery Brook shaft on Washington Avenue.



"Washington Avenue Tunnel Lining Location Map." 2012. Brinnier & Larios. Ulster County Department of the Environment. This map uses the 1909 contract drawings from New York City as a base map, and adds the locations of the sink hole, Tannery Brook shaft, and storm sewers.

APPENDIX H:
Fragmented & Forgotten Exhibit at the Lace Mill

Introduction

"Fragmented & Forgotten: Tracing the Tannery Brook" exhibit was on display at The Lace Mill in Kingston from March 3 through April 29, 2018. Historic maps of the Tannery Brook were shown with digitized maps, historic images, and text to visualize changes in and around the stream over time. These materials helped shed light on the Tannery Brook, and what it has meant to Kingston over time.

The exhibit at The Lace Mill explored the evolving relationship between the Tannery Brook and the Kingston community. It included copies of 29 historic maps, 27 digitized maps, 41 historic photos and paintings, 14 modern-day photos, and 11 excerpts of primary source documents. The earliest map of the brook was from 1685, and the most recent was from 2014. These materials were organized into five eras, and included interpretive text to tell the Tannery Brook's story over time.

Jiamin (Jasmine) Chen, a graduate landscape architecture student from Cornell University, assisted with curating the exhibit. Jasmine also created the digitized map series, based on historic maps, to visualize changes in and around the Tannery Brook with a consistent set of symbology.

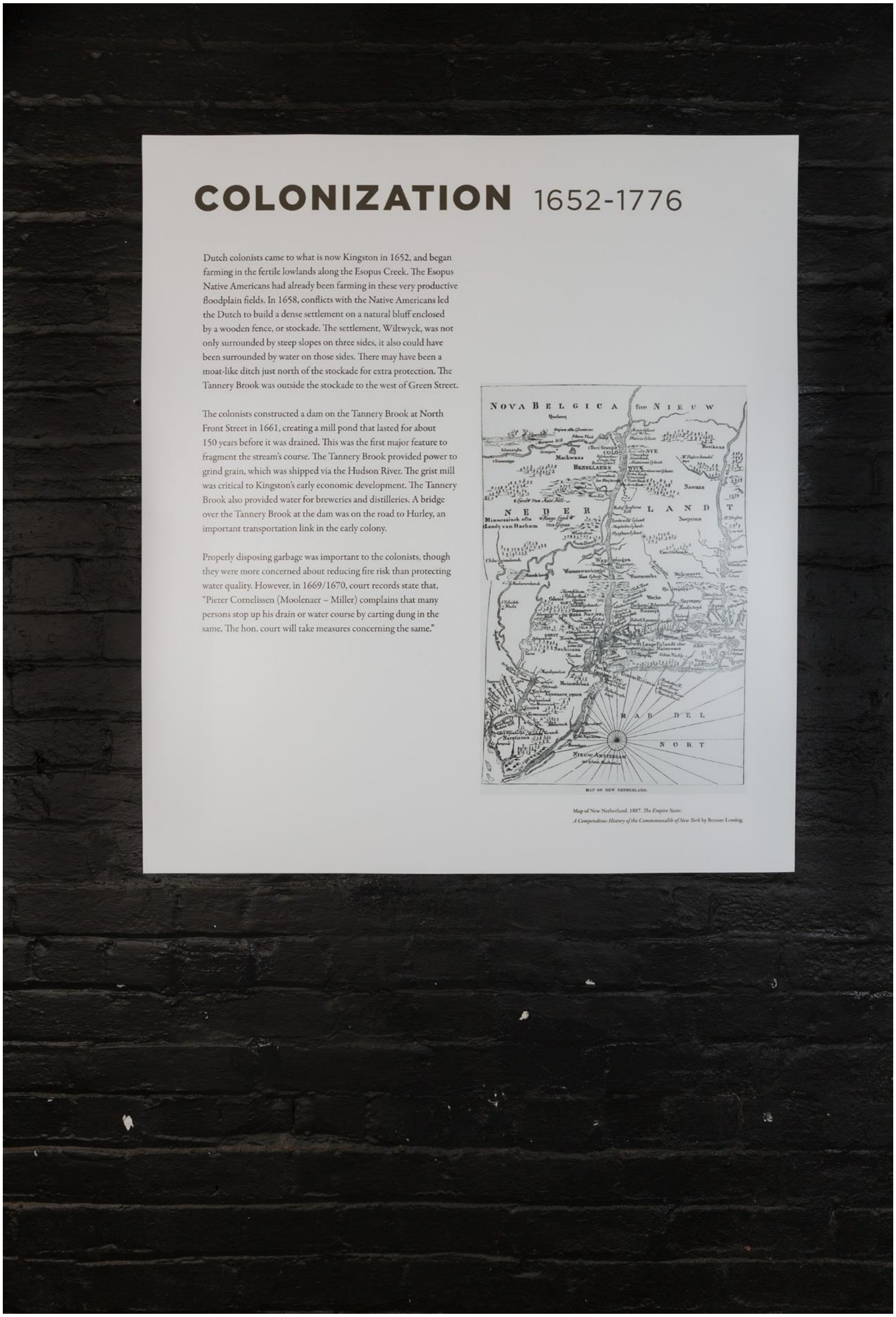
Approximately 185 people visited the exhibit, including residents who live along the Tannery Brook, municipal officials and staff, local history experts, water management professionals, and many others. Although the show was originally planned to be up for one month, it was extended for another month due to local interest. The exhibit not only shared information about the Tannery Brook and its history, but it also created a space for people to gather and have conversations. People shared their knowledge and first-hand experiences with the brook, which added richness to the exhibit and helped identify opportunities for future work.

In addition to open viewing hours, several events were held in the space, including:

- a green infrastructure in Kingston workshop, in partnership with City of Kingston and Ulster County Department of the Environment;
- a lecture on the history of the Tannery Brook;
- two jazz concerts organized by bassist Michael Bisio; and
- a Heal Well Kingston gathering, sponsored by the City of Kingston.

For more information, see:
https://www.tracingtannerybrook.com/fragmented-and-forgotten/

Exhibit photos by Rubi Rose Visuals

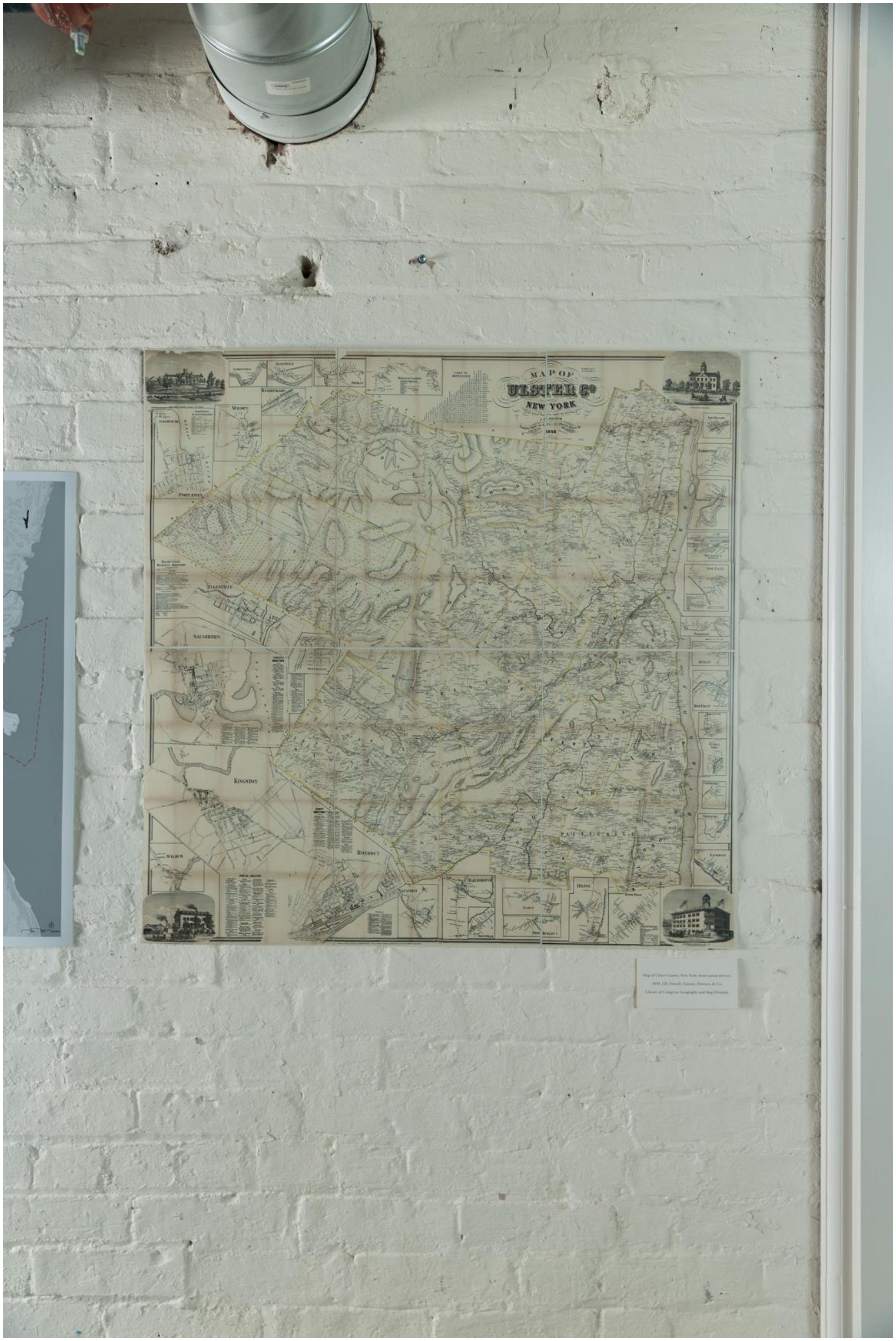

COLONIZATION 1652-1776
Dutch colonists came to what is now Kingston in 1652, and began farming in the fertile lowlands along the Esopus Creek. The Esopus Native Americans had already been farming in these very productive floodplain fields. In 1658, conflicts with the Native Americans led the Dutch to build a dense settlement on a natural bluff enclosed by a wooden fence, or stockade. The settlement, Wiltwyck, was not only surrounded by steep slopes on three sides, it also could have been surrounded by water on those sides. There may have been a moat-like ditch just north of the stockade for extra protection. The Tannery Brook was outside the stockade to the west of Green Street.
The colonists constructed a dam on the Tannery Brook at North Front Street in 1661, creating a mill pond that lasted for about 150 years before it was drained. This was the first major feature to fragment the stream's course. The Tannery Brook provided power to grind grain, which was shipped via the Hudson River. The grist mill was critical to Kingston's early economic development. The Tannery Brook also provided water for breweries and distilleries. A bridge over the Tannery Brook at the dam was on the road to Hurley, an important transportation link in the early colony.
Properly disposing garbage was important to the colonists, though they were more concerned about reducing fire risk than protecting water quality. However, in 1669/1670, court records state that, "Pieter Cornelissen (Moolenaer – Miller) complains that many persons stop up his drain or water course by carting dung in the same. The hon. court will take measures concerning the same."
NOVA BELGICA
NIEUW
NEDER
LANDT
MAR DEL
NORT
MAP OF NEW NETHERLAND.
Map of New Netherland. 1887. The Empire State: A Compendious History of the Commonwealth of New York by Benson Lossing.


THE EARLY REPUBLIC 1777-1871


THE EARLY REPUBLIC 1777-1871

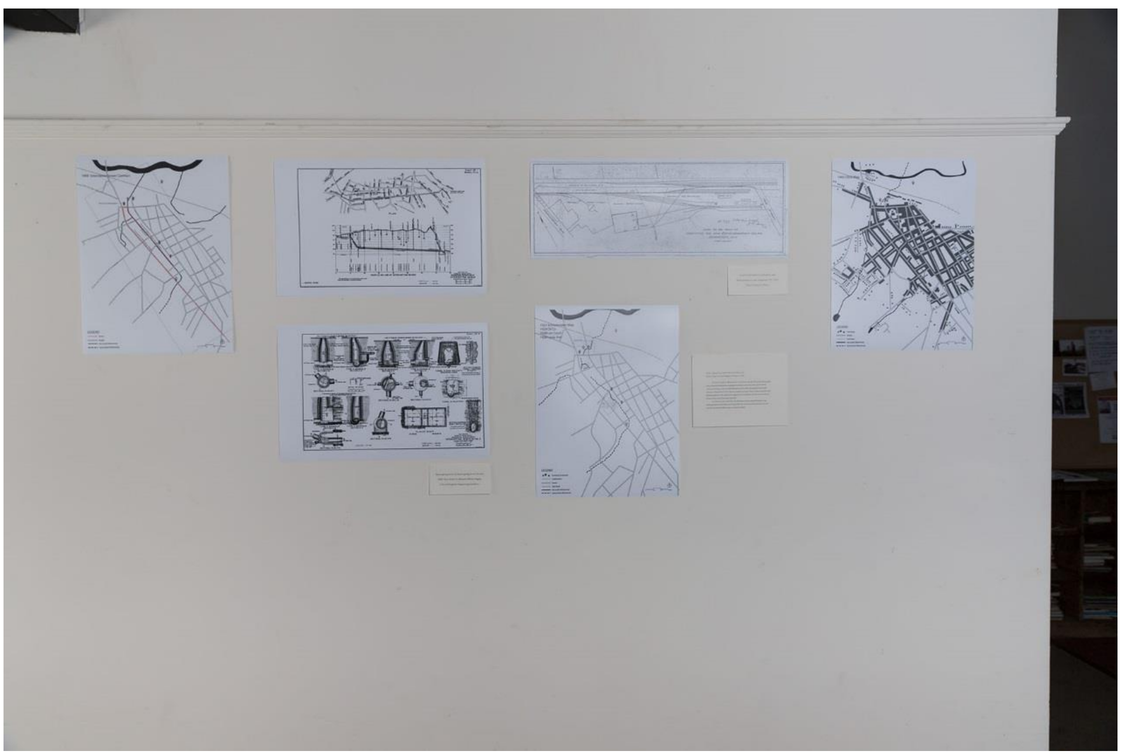

1870 Beers Map
LEGEND


1887 Sanborn Map
LEGEND
ELECTRICAL
ROOM


MAP OF
ULSTER Co
NEW YORK


THE SANITARY CITY 1872-1946
In 1872, the villages of Kingston and Rondout combined to form the City of Kingston. While improving drainage had long been a role of local government, the city was able to hire municipal staff and had more capacity to take on engineering projects. New forms of water infrastructure were emerging. Drinking water infrastructure carried water from the Saw Kill in Woodstock into people's homes in Kingston starting in 1883, and the system transitioned from private to public by 1896. Prior to this, residents relied on well water, and since the colonial era many buildings had cisterns to collect roof runoff for household use.
The first ward-wide wastewater system (1889) collected sewage in a trunk line along the Tannery Brook, and released it into the Esopus Creek. At the time, it was believed that rivers were able to naturally treat waste. The Esopus Creek appeared to have sufficient flows to dilute sewage and reduce the risk to the Village of Saugerties downstream. Sanitary sewers replaced cess pools, water closets, and other rudimentary on-site systems. In 1914, the Kingston Daily Freeman described a sanitary ordinance that required all property owners to connect with the sewer and abandon outside vaults; that year, the newspaper also reported on the "stench" of the "that famous Tannery brook which has been the subject of considerable discussion at board of health meetings from time immemorial."
The original trunk line sewer along the Tannery Brook was only used for about 20 years. In 1909, before construction on the Ashokan Reservoir was completed, New York City's Board of Water Supply constructed a large sewer interceptor 80 feet below Washington Avenue. This tunnel redirected sanitary sewage in Uptown Kingston away from the Esopus Creek and into the Twaalfskill and Rondout Creek. The Board of Water Supply anticipated that the Ashokan Reservoir would reduce flows in the Esopus Creek such that it would no longer be able to dilute the sewage. The City of Kingston eventually constructed a wastewater treatment plant on the Rondout Creek in 1946.
Residential development continued to expand outside the original Stockade area and up the hills west of Washington Avenue. These changes in land use and domestic water use impacted water quality and quantity in the Tannery Brook and the Main St. Brook, its largest tributary. The Main St. Brook does not appear on early maps, likely because this area was not well-known. Main Street was extended past Green Street to Washington Avenue in 1887, then to Johnston Avenue (1896) and Grand View Avenue (1918).
Despite the reliance on the Tannery Brook to convey waste, it still played important role for recreation. William C. DeWitt wrote in 1943, "The Tannery brook was large 60 years ago... We used to try to catch brown trout when the stream rose. Maybe they were only small pike or inferior fish." He also described Carter's Pond, which was constructed on the Tannery Brook south of Lucas Avenue, and was well used for ice-skating in the winter.
CITY OF KINGSTON, N.Y.


STAIR




URBAN RENEWAL
SUBURBAN DEVELOPMENT 1947-1999


1970 Official City Map
ELEVATOR
OFFICIAL MAP OF THE
CITY OF KINGSTON
NEW YORK


TOWARD A SUSTAINABLE CITY?
Hydrology and Habitats

Feedback from Attendees

These quotes were transcribed from video interviews of attendees recorded by Judith Zelda Miller during the opening of "Fragmented & Forgotten: Tracing the Tannery Brook" at the Lace Mill on March 3, 2018.

"Tannery Brook is a stream that is open, part of it is not covered, is not in a pipe, and so I was very drawn to it when I moved to Kingston because I'm from Brooklyn, and I'm not used to seeing to seeing streams just in my neighborhood, running through my neighborhood. So I used to go sort of meditate by the stream, and then I heard that part of it was being covered over, and it started making me think about how many streams are piped underground that we don't notice, and how we could really be retaining more stormwater if streams were reintegrated into urban systems, and how would we go about doing that."

– Julia Farr, Executive Director, Kingston Land Trust

"Once you see where, how the streams ran initially, how they've be re-engineered, you can see where potential problems may arise. And there's other places in the City that have streams that have been buried as well. They're out of scope for this project, but what Emily's done can inform these other areas, as well, as we research them."

– Kevin McEvoy, City of Kingston Conservation Advisory Committee, Kingston Land Trust

"It was interesting to see the extent of the Tannery Brook, you know, we've been localized so much. I knew that it came from as far as Warren Street, we can see Warren Street from our backyard, so I knew that it came from there and worked its way down towards, I guess to Kingston Plaza. But seeing the whole thing from beyond Linderman Avenue and then down was pretty interesting… The reality we know is the fact that because of what's happening at the sink hole, where they have an area which has been filled with grout that was supposed to fix it, that they've taken and they've re-routed the water. It does seem, it's obvious that the water wants to go in the direction it's going. It wants to go through my backyard, it wants to go in that direction."

– Jim Naccarato, Green Street resident

"The Tannery Brook was little more than a mud trench, with a little bit of stagnant water, and once in a while, there would be a little bit of a flow there. But pretty much, not much of anything. And then we had the Washington Avenue sinkhole. And when that happened, they changed the direction of the water, and it came through my backyard. And so, at this point in time, after heavy rains, or with the snow, our backyard floods. So we don't have a Tannery Brook there, we have a Tannery Lake… It floods our whole backyard... Our backyard is fairly large, we're up high, so it doesn't risk coming into our house… We had a swing set down there, that the bottom is all rotted because it sits in the water. We've had some trees develop dry rot, because it sits in the water. It just floods."

– Jim Naccarato, Green Street resident

“There's definitely impacts. Streams will do what they want to do, and they will let themselves be known, in one way or another, if we try to control them… I live by the Family Court building and it's underneath the parking lot there, it's piped underneath the parking lot.”

– Beth Roessler, Hudson River Estuary Program & Green Street resident

“I'm just thinking about, reading here how people got their drinking water, that they had cisterns to collect roof runoff, and thinking about the transition to having a ward-wide infrastructure, and how that happened. And maybe it would be appropriate to use some of the techniques that people were using, like collecting water in cisterns, in the future. Or at least holding water in a big storm, so it doesn't run off into the Rondout Creek and pollute the creek.”

– Julia Farr, Kingston Land Trust

“I think this is just a wonderful addition to the city, this exhibit. Because it's a lot of research, I'm really amazed by all the work she's done. And so I'm just a proud supporter of local art and archiving our history. So I'm really thankful, Emily, for all your great work. I hope you get an A+! … I'm still in the process of learning more things, but it's just cool to see the progress of how this area got established. So it's very exciting. My family used to live in this, well, had a factory in this town, in the '50s, so I am partial because of my family's exposure to this community. It's really nice that it's being brought to different generations who may not know where we came from…”

– Star Nigro, artist

“I'm over at Patriots Place, right up against the south edge of the City of Kingston… We got flooded out 15 years ago, when I ended up with four feet of water in my basement, and since then, we have taken measures to keep it from ever happening again. But I've always been interested to know where that stream went to. I knew it went to Tannery, it had to go to Tannery, because of the lay of the land. But I always wanted to look and see how the pieces went together.”

– Bill More, retired NYS DEC

“I love looking at history through different and weird connections. You know, not looking at the history of Kingston as a city, but looking at the history of Kingston through a brook… Different ways of telling history… There's new ways to interpret things, and by looking at things in a different way, you learn new things all the time.”

– Margaret Stanne, Haviland-Heidgerd Historical Collection at the Elting Memorial Library, New Paltz

Photos of Exhibit and Other Events

Photo by Tracy Stellingwerf.

Photo by Laura Heady


Position and Wayfinding


Map, Part of the Esopus Kill & Lands near
Kingston, NY, 1685, Phillip Welles Swon,
Senate House State Historic Site, Kingston, NY,
Office of Parks, Recreation and Historic Preservation,
SH.1987.20.
Part of the Esopus Kill or River
Copyright © 1973 Yale University Library


WARD 3


TOWARD A SUSTAINABLE CITY?
Severe rain storms in the spring of 2011 caused a sinkhole to open
on Washington Avenue near Linderman Avenue. At this location,
the Tannery Brook enters the tunnel under Washington Avenue


URBAN RENEWAL


Extent of map
LEGEND


Position and Wayfinding


EXIT
COLONIZATION


THE EARLY REPUBLIC

APPENDIX I:
Tracing Tannery Brook Installation at O+ Festival

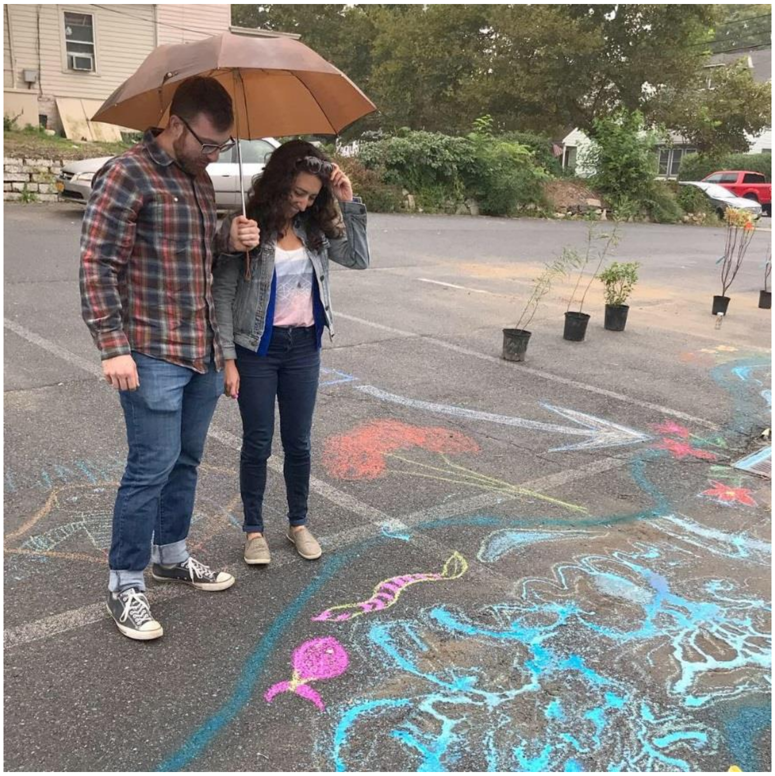
Tracing the Tannery Brook was an exhibit at O+ Festival on October 6-7, 2018 at the Ulster County Family Court parking lot in Kingston, NY. The O+ Festival is a weekend festival of diverse music, arts, and wellness events. Its mission is to empower communities to take control of their collective wellbeing through art, music, and wellness.

Participants literally traced the Tannery Brook by marking the stream's path with chalk and chalk paint on the asphalt. Over 60 people of all ages contributed to the "daylighting" by tracing and painting swirls and ripples to visualize a flowing threat through the parking lot. Homemade chalk paint and sidewalk chalk allowed for a temporary installation.

Participants were asked, "What would be here, if this were a healthy stream?"

This installation also displayed historical information about the Tannery Brook, and described ways the stream has contributed to Kingston over the past 350 years.


DUMP NO WASTE DRAINS TO WATERWAYS




OZARK TRAIL


Ulster County
Family Court


TRACING THE TANNERY BROOK
AGRICULTURE